In The Name of God,  
the Compassionate, the Merciful  

Policy issues

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## Contents

<table>
<thead>
<tr>
<th>Article</th>
<th>Author</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survival of the Interest Rate Based Debt Financing System</td>
<td>Abbas Mirakhor</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Mughees Shaukat</td>
<td></td>
</tr>
<tr>
<td>The Effect of Monetary Shocks on Disaggregated Prices in a Data Rich</td>
<td>Ahmad. R. Jalali-Naini</td>
<td>27</td>
</tr>
<tr>
<td>Environment: a Bayesian FAVAR Approach</td>
<td>Maryam Hemati</td>
<td></td>
</tr>
<tr>
<td>Central Bank Transparency and Monetary Policy Effectiveness</td>
<td>Anton Comanescu</td>
<td>61</td>
</tr>
<tr>
<td>Legal Aspects of Unauthorized Bank Payments</td>
<td>Mostafa Elsan</td>
<td>89</td>
</tr>
<tr>
<td>Bankruptcy Prediction: Dynamic Geometric Genetic Programming (DGGP)</td>
<td>Alireza Bahiraie</td>
<td>101</td>
</tr>
<tr>
<td>Approach</td>
<td>Ali Arshadi</td>
<td></td>
</tr>
<tr>
<td>Financial Stability in Islamic Banking System; the Capacity to React to</td>
<td>Parastoo Shajari</td>
<td>133</td>
</tr>
<tr>
<td>Current World Wide Crisis</td>
<td>Bita Mohebikhah</td>
<td></td>
</tr>
<tr>
<td>A New Mathematical Model to Design Optimum Denomination of Coins and</td>
<td>V.R. Ghezavati</td>
<td>167</td>
</tr>
<tr>
<td>Banknotes Range (ODCBR)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Survival of the Interest Rate Based Debt Financing System

Abbas Mirakhor

and

Mughees Shaukat

Abstract

Evidence has been mounting (over the centuries) that the interest based debt financing regime is under ever increasing distress. All of the earlier crises whatever label they carried—exchange rate crisis or banking crisis—have been debt crises in essence. At the present, empirical research suggests that the debt-to-GDP ratio of the richest members of the G-20 threatens to touch 120% mark by 2014 while by 2020; the U.S and the other major European centers would amass a ratio of at least 150%, with Japan and U.K going to 300% and 200% respectively. Even more disconcerting is the projected interest rate paths on their debts which would increase from now almost 5% to 10% in all cases, and as high as 27% in U.K. Moreover there is also evidence that out of securities worth $200 trillion in the global economy, no less than three-fourth represent interest based debt. It is difficult to see how this massive debt volume can be validated by the underlying productive capacity of the global economy. This picture becomes more alarming when it is realized that the growth of the global economy is anaemic at best while the

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interest rate on debt is sure to exceed the rate of growth of global GDP for the foreseeable future. Hence, a more serious financial crisis may be in the offing and a general collapse of asset prices may occur. This paper argues that the survival of the interest based debt regime is becoming less tenable, as is the process of financialization that has accompanied the growth of global finance over the last four decades. It further argues that Islamic finance, with its core characteristic of risk sharing, may well be a viable alternative to the present interest based debt financing regime.

**Keywords**: Regime Uncertainty, Ambiguity, Complexity, Black Swans, Debt Stress, Islamic finance, Risk-Sharing.

**JEL Classification**: E42, E45, G21, G24, G32
1. Introduction

At a time when the global economy is suffering from a crisis of confidence, structural imbalances, and subdued growth prospects, a growing sense of uncertainty prevailing world over is palpable. Fiscal austerity measures taken as remedial response are further weakening growth and employment prospects, making fiscal adjustment and the repair of financial sector balance sheets all the more challenging. With still rapidly building debt, excessive fiscal deficits, massive unemployment, and falling real-incomes uncertainty has increased regarding how economies, capital markets, and international trade and finance will evolve. Likely scenarios of hyperinflation or prolonged stagflation cannot be discarded easily. Policies appear to be locked into the same regimes that led to the economic and financial collapse earlier. Monumental fiscal deficits and quantitative easings (QE)s have only deepened distortions and heightened uncertainty. Thousands of people have taken to the streets of US cities, and thousands of others in Europe, demanding a fair distribution system. In Europe, concerns and uncertainty about the institutional integrity of the eurozone – key to the architecture of modern Europe – continue to mount.

The World Bank in its latest report on Global Economic Prospects, 2012 suggests that Banking-sector deleveraging is cutting into growth and developing country capital flows, faced with rising funding costs, increased counter-party risk assessments, deteriorating bank-asset-quality, and growing concerns over the adequacy of capitalization. “Even if the threat of a full-blown crisis is somehow averted, elevated fiscal deficits and debts and the very loose monetary policies being pursued in the high-income world, proposes that for the next several years the external environment for both developed and developing economies is likely to remain characterized by volatile capital flows and unsettled business sentiment. As a result, it is becoming harder to gauge the impact of the constant surge in financial market turmoil on the real sector of the economy, but it is almost certain to be negative. How negative is extremely uncertain”. This uncertainty extends to the stability and sustainability of the international economic and financial system.
These developments and the fragility of the global financial setup signal the presence and growing sense of a “regime uncertainty”; uncertainty regarding the benefits and costs as well as the sustainability of the regime of interest rate based debt finance. The search is on for a paradigm shift towards a less volatile and more resilient system. The purpose of this paper is to suggest that Islamic finance provides such an alternative to the present crises-ridden conventional finance.

Before exploring the possibility of such a paradigm or regime shift, it is important to know what is meant by regime uncertainty. To this understanding of risk, uncertainty and ambiguity is helpful; the subject of following section. Before focusing on the concept of regime uncertainty, section three will highlight further the present debt overhang that is creating debilitating fears of contagion and recurrence of full-fledged global crisis. These fears are exacerbated by the complexity of the conventional finance. Section three will discuss the concept of complexity and the need for a shift towards a different financing regime. Explanation of the notion of regime uncertainty will comprise section four. The paper argues that the new regime will need to be based on the idea of risk sharing; the essence of Islamic finance. The last sections will focus on risk sharing and how such a system can create stability and resilience in the global financial system, thus, reduce the frequency and severity of crises that have plagued the global economy.

2. Risk, Uncertainty and Ambiguity

Frank Knight explained that, at times, decisions are made based on available probability distribution of expected events. This is decision making under risk. Unlike risk however, uncertainty describes a situation where a known probability distribution is not available but it is still possible to make decisions with some subjective estimates of probability of outcomes of actions or decisions (Knight, 1921). In the 1960s this view was modified to cover circumstances under which human cognitive ability and information availability are so constrained that even subjective assessment of outcomes was not possible. Ambiguity arises under such circumstances (Ellsberg, 1961;
Erbas and Mirakhor, 2007) where the intensity of “ignorance” can create paralysis in the decision making.

3. Complexity of the Interest Rate Based Debt Finance

To understand the dynamics that have generated the present uncertainty about the interest rate based financing regime, it would also be helpful to first note what is meant by a system and indicate differences between simple, complicated and complex systems. A system is defined as “set of elements standing in interrelations” to one another (Von Bertalanffy, 1969 Revised Edition, p. 38). Or as Meadows (2000, p. 2) elaborates “A system is a set of things—people, cells, molecules, or whatever—interconnected in such a way that they produce their own pattern of behavior over time”. How predictable that “own pattern of behavior over time” may be, depends on the nature of the system in terms of the degree of simplicity or complexity of the rules governing the interrelationship among its elements. A simple system is quite predictable because of the simplicity of its operational rules. For example, old cars had simple starting operations: placing keys in the ignition to start the engine, a simple and predictable system. Complicated systems contain subsets of simple systems but are not reducible to them. Their complicated nature is often related not only to the scale but also to issues of coordination of specialized expertise. Complicated systems are also predictable (Holland, 1995). In contrast to the old cars, newer and more technically advanced automobiles represent complicated systems. Instead of a key in the ignition, push button remotes are used to start the engine. Despite considerably more complicated technologies, modern automobiles are still predictable systems (Mirakhor et al, 2012).

Complex systems contain both complicated and simple subsidiary parts, but are not reducible to either (Goodwin, 1994) since they too have special requirements, including an understanding of unique local conditions (Stacey, 1992). Interdependency and interconnectedness of all the heterogeneous elements that build up such a system, where each part is doing its own thing, carry ability to create emergent phenomenon (crowding effect) with scaling, criticality and self-organization capacity; all in the absence of any central
controller or coordinator (Johnson, 2007). These systems are operated, ruled and governed by feedback loops. Such arrangements are all characterized by “bifurcation points” at which system can either move to more stability and order or to chaos (Prigogine, 1997). There has to be zero defect policy for the system to work in an ordered way. In such a system a small marginal change is capable of creating large impact on the global behavior of the system (Holland, 1995). They are unpredictable and uncontrollable with the added attribute of non-linearity (Lorenz, 1993). Unavoidably, complex systems innately carry with them large elements of uncertainty and ambiguity (Wheatley, 1992). It is impossible for the system to have a stable equilibrium (Buchanan, 2002).

The financial sector is now being increasingly thought of as a system governed by feedback processes or knock-on effects (Johnson, 2007). It means that the system is influenced by past events, nullifying any ‘random walk’ phenomenon (Mandelbrot and Hudson, 2004 and Peters, 1996). The system corresponds to ‘critical state’ phenomena in which the “long-range dependence between the elements can affect massive systemic changes due to small changes in certain parameter”: another important feature that assures the complexity of the system (Bookstaber, 2011). It needs a ‘zero error’ policy for it to function well because when a system is complex it can reach bifurcation points at any time, making the system so sensitive that it can further amplify small changes into large feedbacks. The recent U.S. subprime crisis, as well as the financial crises in Greece and now in elsewhere, can be clearly referred as to as those small marginal changes that have affected the dynamics of the whole system. The system reached a critical state or a perpetually unstable organization of the critical state, where the system became so unstable and unsustainable that it reached to a point of bifurcation: a moment of truth where the system had to implode – as in the recent bust of the U.S. housing bubble or explode – like in the 1990s Asian crisis and now in the present financial crisis. This also explains why the present system has become so sensitive to events that produce ‘black swan’ events (events with very low probability of occurrence but with large impacts).
In early 1940s, a British mathematician, Alan Turing, was perhaps the first modern scientist to formulate complexity. The hallmark of his contribution was a paper he wrote about the growth of biological system in which he put forward the idea of “morphogenesis” (Turing, 1952). He showed that a biological system described by two simple equations with feedback loops among the variables was capable of behaving in totally unpredictable, complex patterned behavior. A decade later, an American meteorologist, Edward Lorenz, had developed models with feedback loops to increase the accuracy of weather forecast (Lorenz, 1963). His models showed two things: unpredictability of weather systems and the significantly large impact of small, marginal changes in local individual element’s behavior on the global behavior of the system. This last point was covered in a talk he gave in 1961 titled “Does the flap of a butterfly wing in Brazil set off a tornado in Texas”\(^1\). This talk made famous “The Butterfly Effect”.

The third prominent intellect that made significant contribution to the notion of complexity is Benoit Mandelbrot who is also the inventor of ‘Fractal Geometry’ (Mandelbrot, 1982). He too showed how a system described by a simple equation (rule) with feedback interaction, is capable of producing unpredictable, infinitely complex patterns. While patterns were easy to generate via computers, describing the patterned behavior of such system mathematically was exceedingly difficult. Whereas Alan Turing had used two simple equations with feedback interaction to describe the growth of biological system, Mandelbrot used only one such equation that generated similar unpredictable, infinitely complex patterns.

Mandelbrot also made an equally significant contribution to finance where he argued that all the theories in finance were wrong because they relied on Gaussian (normal) probability distributions and the Brownian motion, both of which assume regularities. He pointed out that nearly all economic and financial variables, particularly stock prices and commodity prices, behaved irregularly. Their behavior, Mandelbrot argued, was better described by ‘Fractal Geometry and mathematics’ than by Gaussian

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\(^1\) Edward Lorenz's talk for the 139th meeting of the American Association for the Advancement of Science in 1972.
distribution and Brownian motion (Mandelbrot and Hudson, 2004) as they are instead characterized, Mandelbrot suggested, by jumps rather than smooth motion. He pointed out that nearly all speculative financial variables, particularly stock prices and commodity prices, behaved irregularly.¹ Since finance theories were wrong so would be their predictions; the recent financial crises has vindicated his claims.

Peters (1996) argued the need for a new way of looking at markets behavior. He claimed (similar to Mandelbrot) that the assumptions of efficient markets and rational investors in mainstream theories are a fallacy. On the basis of ‘chaos theory’ he showed that in fact markets are non-linear dynamic systems: with feedback effects, criticality levels as well as fractal in nature. He further argued that such a system is always far from equilibrium. Ilya Prigogine (1980, 1989 and 1997) suggested that for a complex system, there is a “point of bifurcation”, a moment of truth, for the system to choose which path it follows. Chaos Theory suggests that a complex system approaching a bifurcation point becomes so sensitive that it can amplify small changes into large feedbacks. Decisions made at such a point lead the system either toward greater chaos or toward higher order (Mirakhor and Hamid, 2009, p. 231). It appears that the “point of bifurcation” has been operating to increase regime uncertainty. At every ‘bifurcation point’ reached, policy makers seem to have made decisions that have rendered the system more unstable.

Finally, Nassim Nicholas Taleb argues (2007/2010) that there are events with very low probability of occurrence but with significantly large impact; quite reminiscent of the ‘Butterfly effect’. These events he termed as ‘Black Swans’ due to their rare appearance. Recently, the global system has experienced events that would have been thought of as low probability events not long ago. These include, inter alia, the down grading of U.S from its ‘AAA’ rating, the looming collapse of the much hailed Eurozone, the effort

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¹. Louis Bachelier (1900), in his thesis, the theory of speculation, developed the notions of stochastic process characterizing financial variables. Two main stochastic processes have become known in finance: the random walk and the martingale processes. A more encompassing approach to uncertainty uses Levy processes that allow for both jumps and smooth motion.
by Switzerland to convince the world that Swiss franc is not a safe haven, the Brazilian suggestion of bailout of advanced economy by emerging markets and China’s contemplation of buying Italy’s debt. The list can go on.

Looming in the back ground of the present uncertainties in the global economy there is a potential event, termed as “the mother of all black swans”, the effects of which may be chaotic global economy: contagion-riddled events of sovereign default. It can be stated, by way of summary that: (i) In a complex system, elements are independent, adaptive and interactive; there is a feedback process at work; (ii) The system can reach criticality and unexpected ‘bifurcation points’. (iii) Such systems are characterized by an unpredictable, infinitely complex patterned behavior; (iv) Small, marginal changes have significantly large impact on such system’s behavior; and (v) There is a limitation to the cognitive ability of human mind to understand, describe, predict and control such system’s behavior.

The global financial crisis of 2007/2008 and its continuing adverse economic and social consequence, as well as the failure of significant policy actions to elicit the desired response, seem to provide evidence that the global financial system displays the characteristics of a complex system. Added to the shock of occurrence of “fat tail” events, increased poverty and worsening distribution of income and wealth in individual and collective economies have intensified regime uncertainty. Such doubts about the sustainability of a system based on the interest rate debt financing had been expressed as early as 1930s by John Maynard Keynes. Focusing on the interest rate mechanism, Keynes argued in his book, *The General Theory of Employment, Interest and Money* (1936) that market capitalism, left to it-self, would create two major problems which, if not addressed, would cause system failure. These are (i) poor income and wealth distribution and (ii) the fact that this system is incapable of creating full employment. A major cause of these problems, Keynes asserted, was the interest rate mechanism which constituted “the villain of piece” (Mirakhor and Krichene, 2009). Keynes solution was the “euthanasia of entire” by socializing investment through which financial capital would be provided for investment without the intermediation of the
rent-seeking class of the money lenders. The failure of socialism in the 20th century, however, has made this solution unpopular.

A fact that can be discerned from the historical analyses of nearly all financial crises is the potential destabilizing role of the interest rate mechanism in the debt-growth dynamics of the economies. In the 1920s a young mathematician/philosopher, Frank Ramsey, had published a paper about analyzing the interaction between interest rate and growth rate (Ramsey, 1928), a work that was ignored by economists until the 1960s. He used the interaction of the rate of population growth, the growth of interest rate and the growth of economy to deduce the following: if the rate of economic growth exceeded both the other rates i.e. the rate of interest and the rate of population growth, the economy would grow. A steady state was when all the three rates were in equilibrium; however where ever the interest rate growth surpassed the growth of the economy and the growth of population, economic activity would begin a downward spiral. This seems to be the debt dynamics at work in the global economy presently. Question arises as to whether there is an alternative to the present dominant global finance system. Perhaps a more practical alternative would be to step back from targeting the interest rate mechanism and focus on the incentive structure that has rendered the interest rate based debt financing such a destabilizing force in the global system. This can be accomplished by reorienting the system from relying on risk transfer and risk shifting to risk sharing.

4. The Regime Uncertainty

The idea of “regime uncertainty” (Robert Higgs, 1997) argues that a major cause of the intensity and duration of the Great Depression was the depth of the uncertainty (ambiguity) surrounding the policy regime of the time and its economic and financial consequences. This type of uncertainty can arise from many sources, ranging from simple tax-rate increases to the imposition of new kinds of taxes to outright confiscation of private property. It can also arise from various sorts of regulation, for instance, of securities markets, labor markets, and product markets. The security of private property rights rests not so much on the letter of the law as on the character of the
government that enforces, or threatens, presumptive rights. Henry Morgenthau the Treasury secretary in President Roosevelt administration in the 1930s encapsulated the wide ranging uncertainty as follows:

...“Uncertainty rules the tax situation, the labor situation, the monetary situation, and practically every legal conditions under which industry must operate. Are taxes to go higher, lower or stay where they are? We don’t know. Is labor to be union or non-union? . . . Are we to have inflation or deflation, more government spending or less? . . . Are new restrictions to be placed on capital, new limits on profits? . . . It is impossible to even guess at the answers”. (qtd. in Higgs, Depression, War, and Cold War, p. 16)

The most serious problem facing the global economy today is the situation of debt overhang which has made the present system to reach a point of criticality and bifurcation; creating debilitating fears of contagion and recurrence of full-fledged global crisis. Krugman (1988) coined the term ‘debt overhang’ and asserted it as a situation in which “A country has a debt over-hang problem when the expected present value of potential future resource transfers is less than the debt”. With high debts, interest payments also increase, thus increasing both the burden and servicing of debt. Rising debt is a drag on macro-economic stability, growth and development. Large part of theoretical and the empirical analysis have focused on the effects of debt accumulation and its impact on overall economic growth. Contributions by Buchanan (1958) and Meade (1958); Pattillo et al. (2002, 2004); Chowdhury, (2004); Clements et al. (2003); Presbitero (2005); Cohen (1993); Elbadawi et al. (1999); Cordella et al. (2005); Imbs et al, (2005) and Checherita and Rother (2010), all point to a negative and a non-linear relationship between excessive debt and economic growth trends.

The 2007/2008 global financial crisis has been studied and analyzed extensively by now and a variety of causes have been suggested. By far the most expansive study has been by Reinhart and Rogoff (2009) which contends that all financial crises, whether currency or banking crisis, are at root debt crises, including the Asian Crisis in the late 90’s. In another paper
(Reinhart and Rogoff, 2010) the authors studied the period of 200 years for 44 countries for which data was available. An important insight of this study is that the growth of the economy is adversely affected as the ratio of debt-to-GDP goes beyond 30 percent and nears 100 percent, eventually creating a situation where the GDP is only able to service the interest payments. The IMF reached similar conclusions in its “post-mortem” of the Asian financial crisis in the late 90s and recommended a safe level of government debt-to-GDP of no more than 25 percent. They further advised avoidance of debt-creating flows; an advice that was not taken by the advanced economies. Rogoff (2011) suggests that there are now $200 trillion of financial paper in the global economy, of which nearly 75 percent or US$150 trillion is in interest-bearing debt. The global GDP in 2011 is estimated optimistically at US$65 trillion. The question is how the underlying real global economy, growing at rates below the growth of global debt, will be able to validate this debt?

According to recent IMF Fiscal Monitor, the average debt per working age person in advance economies will increase from $27,600 in 2007 to $62,000 in 2016 and from $1,500 to $2,200 in emerging markets. In 2009, the IMF estimated that gross general government debt in high-income advanced G-20 economies is expected to grow from 78 percent of their GDP in 2007 to 120 percent in 2014, an increase of 40 percent over a 7 year period. These countries suffer from high unemployment, fiscal instability, low capacity utilization and high debt and leverage. The stress and strain on the international trade and financial system and its associated arrangements did not suddenly become apparent after the 2007/2008 global crisis; in the 1990s Japan, Russia, Argentina, Brazil, and Mexico were sending distress signals (Mirakhor, 2002). Neither the signals nor the lessons of these crises made any noteworthy impact on the way the world economic system and its policies were being steered. Andrew Sheng (2009) suggests that the crisis would have been evaded had the system learned the lessons of the Asian crisis:

“Whilst the emerging economies learned the lessons of 1997/98 crises, put their macroeconomic policy house in order, reduced their exposure to sudden stops, and accumulated reserves, most advanced economies went in the opposite direction. They reduced their savings,
increased consumption, ran fiscal deficits and accumulated large debts. Observers suggest that Ireland, Portugal and Greece are only the tip of the axiomatic iceberg and that there is a heightened risk of the emergence of an even more serious global debt crisis”.

The lessons had been distilled most effectively by the IMF, from the “post-mortem” analyses of the Asian, Brazilian, Argentinian, Russian, Mexican crises of the late 90s and early 2000s. Reforms and remedies were suggested but were only implemented, most strongly, in case of emerging and developing countries. The advanced countries perceived their economies immune to the forces of instability. Growing vulnerabilities, however, built up the pressures that proved dramatically the folly of such perceptions.

John Mauldin and Jonathan Tepper in their latest book titled “The End Game” have described the present situation as a debt ‘super cycle’; referring essentially to the decades-long growth of debt from small and manageable levels, to a point where bond markets rebel, (translating into an ‘effective default’) and the debt has to be restructured or reduced if not formally defaulted”. They refer to the current situation as an End game, where the end of the global debt super cycle is inevitable as it is no more sustainable. They state very clearly:

“The debt laden situation is going to cause a lot of pain. It is not a question of pain or no pain; it is just when and how we decide (or are forced) to take it. There are no easy paths, but some bad choices are less bad than others”. ... “We have shifted the crisis from homebuyers to banks and then finally to government. There is no one else to step in. We are at the End game, a point of criticality in the system.

Uncertainties, ambiguities and complexities governing the present architecture and configuration of policies, seem to exacerbate the perception that the present financing regime is unable to mitigate effectively the risks to the global economy. Hence, there is a palpable anxiety and growing concern leading to the search for an alternative to the present interest-based debt financing regime.
4. Islamic Approach to Money and Finance

Islamic finance is based on Quran and Sunnah. It prohibits interest rate based debt contracts, although free-of-interest lending, called *qard hassan*, is permitted. Islamic finance can be envisioned as a two-tier financial system:

- A 100 percent reserve depository and safekeeping banking system for domestic and international payments.
- A risk-sharing investment banking that places real saving directly in private or public projects or indirectly via the stock market. Investors are shareholders.

The first sub system keeps money deposits in trust and settles payments via clearing, withdrawals, and other forms of payments. The second part of the system receives savings, which it invests in productive projects or in more liquid investment such as mutual funds or stocks. Depositors receive transferable or marketable shares that enable them to liquidate their investment if they chose to do so. They share in profits and losses as well as in capital gains and losses. Islamic capital markets intermediate between saving units and investing units through risk sharing. They would include investment banking, stock markets, mutual funds, exchange-trading funds, and other forms of intermediary risk-sharing institutions.

The objective of Islamic finance is to promote sustained growth and full employment thus contribute positively to poverty alleviation, and, ultimately, to economic and social justice. Growth cannot be achieved without capital accumulation. Investing in capital is the only way for achieving growth and employment. Islamic finance, being based on sharing the risk of an activity rather than on interest rate driven debt contracts, contributes efficiently to capital accumulation and is immune to financial instability and speculation. It is based on growth solely and allows no wealth redistribution via interest rate based debt contracts; it insulates an economy against banking failure and stock market crashes that have had a constant presence in the conventional system (for the proof of existence of an stable non-inflationary economy operating in a non-interest rate environment see Mirakhor 1990/1993).

It can be argued that Islamic finance precludes capital markets’ volatility because in this system the close relationship between the real and financial
sectors pre-empts misalignment of rates of return to finance, the rates of real growth of the economy and net rate of profit. It is based on risk taking and risk sharing.

5. Risk Sharing\textsuperscript{1}: a Rule-Based System

Investors or portfolio managers in general face two kinds of risks. The first is systematic and the other idiosyncratic. The former refers to risks that are macro-economic in nature and are posed by overall economic settings. These risks are un-diversifiable hence uninsurable. Only effective macro-economic policies and international economic and financial coordination can mitigate such risks. Unsystematic or idiosyncratic risk, on the other hand, relates to risks that are individuals or firms specific, emanating from risk of shocks to a firm or an individual income. Such risks are diversifiable, therefore, insurable. High correlation between consumption and income creates vulnerabilities to income shocks. However these can be mitigated through risk-sharing arrangements that lessen reliance on only one source of income. Therefore, risk sharing reduces the correlation between income and consumption that, in turn, leads to consumption smoothing (Mirakhor, 2011b).

Risk sharing -the essence of Islamic finance- serves one of the most important desiderata of Islam i.e. the unity of mankind. Islam is a rules-based system in which a network of prescribed rules governs the socio-economic-political life of the society. Compliance with these rules renders the society a union of mutual support by requiring humans to share the risks of life (Mirakhor, 2011c). The epistemological roots of risk sharing as an organizing principle of Islamic financial system is discernible from the verse 275 of chapter 2 of the Quran. This verse, in part, decrees that all economic and financial transactions are conducted via contracts of exchange (al-Bay’) and not through interest-based debt contracts (al-Riba). Since in the Verse the contract of exchange appears first and no-riba thereafter, it can be argued that

\textsuperscript{1}For a more detailed vision of the Islamic alternative financial system see, H. Askari, et. Al, (2012),” Risk Sharing in Finance: the Islamic alternative”, John Wiley.
requiring contracts to be based on exchange constitutes a necessary condition and “no-riba” the sufficient condition of existence of an Islamic financial system. Together, these conditions constitute the organizing principle of that system. The necessary condition (al-Bay’) and sufficient condition (no riba) must be met for a contract to be considered Islamic (Mirakhor, 2011c). Classical Arabic Lexicons of the Qur’an define contracts of exchange (al-Bay’) as contracts involving exchange of property rights claims in which there are expectations of gains and probability of losses (Mirakhor, 2010; Mirakhor, 2011b). By entering into contracts of exchange, parties improve their welfare by exchanging the risks of economic undertakings, thus allowing division of labour and specialization.

The understanding of al-Bay’, the exchange of one set of property rights' claim for another, as the necessary and “no-riba” as the sufficient condition have important implications. Exchange requires the freedom to contract for the parties involved and this implies freedom to produce, which then calls for well protected property rights to allow and facilitate production. For exchange to take place, there is a need for markets and then for rules that govern behavior of market participants. Rules need enforcement and regulation to keep the flow of information smooth thus reducing transaction costs. These rules of market behavior include: trust, faithfulness to the terms and conditions of contracts, good governance, honesty and transparency in social dealings, rules of property rights and market behavior, contract enforcement, distribution and re-distribution. It can be argued that full compliance with these rules reduces the informational problems and transaction costs thus rendering the system efficient (Askari, et al., 2010).

Risk and uncertainty are undeniable facts of life. As was discussed earlier, uncertainty stems from not only the lack of information but also from ignorance of knowing the response and behavior of others under such conditions. Question arises as to why risk and uncertainty exist. This question becomes more acute for those who believe in the supreme Creator who

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1. See also, for example, Al-Tahquiq Fi Kalamat Al-Quran Al-Karim; Lisan Al-Arab; Mufradat Alfaz Al Quran, Arabic Lexicon, among others. These sources define al-bay’ as “mubadalati al-maali bi al-maal”. In English this can be rendered as “the exchange of one set of property rights claim for another.”
creates all things. Since it is believed that existence of risk and uncertainty is a source of difficulty for humans, a Creator-centric question also arises: why create risk and uncertainty for humans? Bartholoemu, (2008) argues that “a plausible argument for the necessity of risk is that it serves as an important ingredient in the recipe of full human development. It provides the fertility and diversity of experience to develop our skills and personalities” (p.230). The Qur’an, on the other hand, provides a more compelling explanation: humans are subjected to tests throughout their lives to allow them a sense of the degree to which they, individually and collectively, are rule compliant (see for example verse 155: chapter 2, 2:76, 2:29, 126:9, and also verse 7: chapter 11). Without risk and uncertainty, testing would not be possible (Mirakhor, 2009). To ease the intensity of anxiety in dealing with tests and, therefore, reduce uncertainty and demand on humans’ cognitive ability, the Qur’an prescribes rules of behavior. Principle among these rules is that of risk sharing ordained by the Qur’an.

It can be argued that a financial system based on risk sharing would be more stable than the conventional dominant system which is based on risk transfer and, more and more, on risk shifting. The sources of this stability are the operational characteristics that remove major sources of volatility and instability. Among these characteristics are the following:

- transparency, trust and faithfulness to terms and conditions of contracts;
- close relationship between finance and the real sector activities such that the rate of return to the latter determines that of the former;
- asset/liability risk matching;
- coordinated asset/liability maturity structure;
- asset/liability value matching such that the value of both sides of the balance sheet move simultaneously and in the same direction in response to changes in asset prices; and
- limitations on credit expansion and leverage, naturally arising from the need for credit growth that is tied closely to the expected rate of growth of the real economy.
It has been shown that a system based on these operational characteristics, would be stable and capable of producing employment, income and output growth (Askari, et al., 2010). The full range of instruments of such a financial system would be expected to run the gamut of the spectrum of instruments from short-term, liquid, and low-risk financing of trade contracts to long-term financing of real sector investment. The lower end of the spectrum would provide financing of sales and purchases of products already produced to allow greater production, thus, greater employment of resources. At the higher end, it would provide financing for planned production in the future; all financing taking place through risk-sharing contracts (Mirakhor, 2010). In such a system there would be no opportunity for pure financial transactions, those that have no relation to the real sector of the economy (Mirakhor, 2011a).

6. Global Risk Sharing

One of the most vital arguments put forward in favor of globalization was that of improved risk sharing that would result from intensified human interaction across the world. On theoretical ground, this would mean expecting much greater degree of risk sharing between and among economies - resulting from greater freedom of movement of resources, and hence, providing as a major source of consumption smoothing in the world economy. These developments were expected to lead to progress toward market completion – a condition of optimal risk sharing posited in Arrow’s conception (Arrow, 1971). Or, at least, progress could have been expected toward the design and use of Arrow Securities, with pay offs contingent on the performance of the underlying asset, for example, equity-based securities with close links to the real sector of the economy (Mirakhor, 2011a).

Theoretical Research has demonstrated sizeable potential welfare benefits of risk sharing. However, empirical studies have shown only marginal gains in risk sharing from globalization. For example, a study by Kim, et al. (2005) showed that even in the fast growing East Asia-10 countries, the size of the

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coefficient of risk-sharing was very small and some were negative (Indonesia and Malaysia). Analyses of the pre-crisis data shows a fast growing, debt-creating process in the global financial system with increasingly tenuous links with the growth of the real economy. Increased debt-creating flows, a characteristic of financial globalization in the run up of 2007/2008 crises, does not improve risk-sharing, as they either transfer or shift risk. More importantly, risk-shifting or risk-transfer financial transactions led global finance toward decoupling from real sector activities with the growth of the former outpacing that of the latter by double-digit multiples, intensifying the risk of “sudden stops” (Mirakhor, 2011a).

The contribution of Islamic finance to the growth of the real sector has so far fallen well short of expectations. Perhaps the main reason has been the fact that, growing within the conventional finance framework, the practitioners and financial engineers of this new asset class had to design instruments that resembled those prevalent in the host system without violating the “no-riba” sufficient condition. This meant creating instrument with tenuous relationship to the real sector to weaken the risk perception of Islamic finance held by market players. Hence, Islamic financial industry focused on portfolio behavior with strategy of asset concentration in short-term maturities, and real estate in the medium-to-long-term maturities, thus creating vulnerabilities. Aside from these problems, there is a risk of path dependency: the risk that the industry will continue following the same pattern of behavior because it has proven profitable thus far. This growing complacency and doing “business as usual”, runs the risk that path dependency will render deviations from a truly Islamic finance irreversible. This would mean continued development of debt-like instruments that are low risk and are devoid of risk-sharing elements. After all, finance is well aware of the theory of “spanning”-where one basic asset can span into an infinite number of derivative instruments. This theory served as the basis for the rapid development of debt-based derivative markets world-wide which eventually undermined the stability of global finance.

In their defence, the industry players argue that “our clients” are not interested in placing their funds at risk thus discourage us from risk sharing.
Apparently, this argument is unaware that, conceptually, there is a difference between risk taking and risk sharing. The former is prior to the latter. The risk of a given project in the real sector is determined in that sector before the financial sector seeking finance. It is at the point of financing where the decision regarding the modality of financing – risks sharing, transfer or shifting – is made. The nature and magnitude of risk taken remains the same and immutable as it enters the financial sector seeking funds. Industry players display a further dimension of inertia in resisting risk sharing. This relates to the conceptual “framing” of Islamic finance.

Framing refers to the fact that people’s response to risky situation depends on how they form their perception of a given situation and that depends on how an event is formulated. People react differently to the same situation when it is framed in alternative formulation. Framing is closely related to the idea of “prospect” which refers to perception of gains or losses attached to decisions. The way prospects are framed can lead to inconsistent behavior; if the same objective outcome is framed differently in terms of gains and losses, people respond differently. Since losses, are given greater weight than corresponding gains, people are in general loss averse. If the outcome is framed either as a gain or loss, people prefer to choose gain. For example, the prospects of 10 percent loss and 90 percent gain can be framed focusing either on the probability of the loss or the expectation of the gain. It can be argued that a major reason for the inertia in the industry for resistance to progress toward risk sharing is due to the inability of the stake holders and practitioners to first understand and then frame risk sharing prepositions correctly and effectively.

While the disappointments with the present performance of Islamic finance industry is understandable, it should be noted that the industry has a short history in which it nevertheless has demonstrated remarkable growth. Perhaps it is this performance that has triggered evidence of growing interest in non-interest rate based finance. Indications are that emerging markets and developing economies are actively considering adoption of instruments of Islamic finance. Few are leveraging the “first-mover” status of Malaysia in education, manpower training and instrument innovation in Islamic finance to
introduce their own brand of risk-sharing method of financing. If these efforts succeed, perhaps even the benefits of emerging multiple growth centers in the global economy will be further enhanced with greater stability and resilience in the supporting financial transactions through risk sharing (Mirakhor, 2011c). Governments, particularly in Malaysia, have been a major source of support for the growth of Islamic finance. The same support can extend risk sharing to government finance. Instead of issuing a debt based bond to raise funding, governments can use equity participation securities for such funding. These instruments can be issued in low denominations and traded in the secondary markets. This would allow ordinary consumers and investors to participate in the process of owning a share of their government’s activities. These instruments with the incentive for wide participation of the population could well enhance social solidarity and, perhaps, even an incentive structure for strengthened governance. Such alternative methods of financing government expenditures would be viable particularly in the Asian economies with high saving ratios.

Risk-sharing could also be an effective alternative to the debt-based ways and means of helping European countries facing sovereign debt crises. For example, Eurozone could issue long-term securities with pay offs based on the GDP performance in these countries. Similarly, China could buy Italian GDP-based securities rather than the consideration reportedly being given to purchase of Italian debt. This type of risk-sharing instruments has been proposed by analysts for some time now. Shriller (2003), the first to suggest this type of “macro-market” instruments, believes that the benefits of risk sharing are substantial but have yet not materialized due to the limited availability of appropriate instruments. The present regime uncertainty has created a valuable opportunity for risk sharing based finance as a viable alternative to the interest rate based debt financing.
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Abstract

Price stability has been the foremost task of monetary policy. The information relating to the response of prices to monetary policy shocks is essential for conducting monetary policy in general and for inflation targeting of central banks in particular. Most of the published empirical studies analyze the response of an aggregate price index like CPI or a consumption deflator and their rates of change to monetary shocks. A limited number of studies that examine the effect of monetary shocks on disaggregate prices use vector auto regression models for the analysis. The results of these studies show that some disaggregated prices increase slightly in response to a contractionary monetary shock. This finding can be inconsistent with the standard theory and is referred to as the "price puzzle" in literature. Therefore,

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a body of new literature (Bernanke et al. 2005, Boivin, Giannoni and Mihov 2009) that utilizes factor augmented VAR (FAVAR) approach to analyze the effect of monetary policy shocks and finds no evidence of a price puzzle. In this paper we use a Bayesian FAVAR (BFAVAR) framework to examine the impulse response function of 12 sub-categories of CPI to one standard deviation in monetary base growth rate in Iran. Our two main findings are: (1) monetary shocks have a lagged effect on disaggregated prices and most prices respond to a monetary shock with delay; (2) there is a substantial difference amongst the 12 CPI sub-categories in terms of their response to an increase in monetary base growth rate. Contrary to the existing studies based on standard VAR model, and in line with FAVAR based studies, we also find that price responses don’t display a price puzzle in the case of Iran.

**Keywords:** Disaggregated prices; factor models; factor augmented VAR; Bayesian analysis; Gibbs Sampling, price stickiness, inflation persistence.

**JEL Classification:** C32, C43, E52, E58.
1. Introduction

Most existing studies have tried to analyze the reaction of prices in response to monetary shocks by looking at aggregate price measures, such as the consumer prices index (CPI) or personal consumption expenditure (PCE) deflator. However, the reaction of aggregate price measures to monetary shocks may not accurately display inflation dynamics and pricing behavior at the micro level (Aoki 2001). This is because the behavior of disaggregated prices can be substantially different from the aggregated price index—due to the presence of idiosyncratic demand and supply conditions in a particular sector or government-imposed price controls. Relatively few studies that examine the effect of monetary shocks on disaggregate prices use vector auto regression models for the analysis. The results of these studies show that some disaggregated prices increase slightly in response to a contractionary monetary shock, which can be inconsistent with the standard theory known as the "price puzzle".

In light of increasing interest in the behavior of disaggregated price dynamics in the relevant literature in the recent years, this paper studies the responses of disaggregated consumer prices to monetary shocks. Our focus is on the differences across the main categories of CPI. We use a factor augmented VAR framework to examine the impulse response function of 12 categories of CPI to an increase in monetary base growth rate in Iran. In this paper we use a Bayesian method for estimating the FAVAR model. Aside from the fact that the Bayesian method has improved the empirical results, we prefer Bayesian estimation to the two-stage procedure for three reasons: first, Bayesian confidence bands for impulse responses have a firmer theoretical base and their performance for small samples is superior to

1. Interest rates are set administratively in Iran and do not exhibit sufficient variation with respect to the inflation rate and output. Changes in money base are more correlated with price changes and in some respects are more reflective of change in the monetary policy stance.
2. The other approach for estimating the FAVAR model is a two-step principal component method. In the first step, the common factors are estimated using a large data set. In the second step, the vector auto regression model which contains factors as regressors is estimated (Bernanke et al., 2005).
bootstrap confidence bands which are commonly used in the two stage procedure\(^1\). Second, in Bayesian estimation technique, the procedure of factor extraction and the VAR estimation are done simultaneously. Therefore, unlike the two-stage approach, in Bayesian estimation, the dynamics of factors are considered explicitly. Third, Bayesian analysis technique creates the possibility of including the results of previous statistical studies about the parameters and factors as prior information in the analysis\(^2\). While, in non-Bayesian approaches (classical analysis) it is not possible to incorporate the prior information surrounding the parameters of the model.

The rest of this paper is structured as follows: section two reviews the FAVAR literature as well as the studies done in the context of examining the effect of monetary policy shocks on disaggregated prices; section three sets out the methodological approach used and the next section describes the data set used for estimating the common factors; section five is about the BFAVAR estimation procedure and the factor extraction; in section six, the sources of fluctuations in disaggregated prices are examined; section seven presents the results of the study; section eight presents the concluding remarks and provides some policy implications.

2. Literature Review

We first describe the limitations of vector auto regression models and briefly mention the applications of dynamic factor models to remedy these problems in the analysis of monetary policy. We then review the studies that examine the effects of monetary policy by using FAVAR model and then proceed to review the studies concerning the effects of monetary policy shocks on disaggregated prices.

After introducing the vector auto regression (VAR) methods by Sims (1986), this approach has been used by numerous studies in order to identify and evaluate the effects of monetary policy shocks on macroeconomic variables. The VAR methodology became the standard approach in the

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1. Due to the presence of "generated regressors" in the second step of this procedure, Bernanke et al., implements a bootstrap procedure based on Kilian (1998) for taking into account the uncertainty surrounding the factor extraction.

2. Through the use of informative prior distribution
monetary policy analysis. In spite of the advantages of VAR models, this methodology has not lacked criticism. Bernanke et al. (2005) argue that despite the extensive applications of standard VAR models, they potentially create at least three possible problems. First, monetary authorities examine so many macroeconomic series in their decision-making process. On the other hand, in order to save degrees of freedom, the number of variables used in standard VAR models is relatively small. Therefore, taking into account only a small fraction of information used by monetary policy makers in central banks may lead to an accurate evaluation of the monetary shocks. The best illustrations of this problem are price puzzle. The result observed in many studies using VAR model for the analysis is that a contractionary monetary shock is followed by an increase in inflation (rather than a decrease as standard economic theory would predict). Sims (1992) provides an explanation for the price puzzle based on the fact that the VAR does not include series that capture future inflationary pressure. For solving this problem, Sims includes two additional informational variables: the exchange rate and a commodity price index. In his six-variable VAR model, the size of the “price puzzle” decreased. The implication of this result is that the information which is included in a data set used by the policymakers might not be captured by small-scale VAR models. Bernanke et al. (2005) argue that if we accept Sims’s explanation, then not only the price response is inaccurate, but all of the estimated responses from the standard VAR are also inaccurate. Second, although, economic concepts such as economic activity cannot be represented by a single variable, in the standard VAR framework, researchers have to select observable indices like GDP or employment to represent theoretical concepts. Third, the impulse response functions are observed only for a small number of variables included in the VAR model. However, in practice, policy makers and researchers are interested in evaluating the effect of shocks on a larger set of macroeconomic variables further than the basic variables contained in a standard VAR model. For instance, in order to assess the impact of monetary shocks on the level of economic activity, in addition to GDP and industrial production, it is essential

1. See also Senbet (2008), p.2.
to look at the response of, say, employment, private consumption, inventories, housing starts and so on to the shock.

To remedy these problems, Bernanke et al. (2005) propose a combination involving the factor analysis and the VAR analysis. This approach allows us to summarize a large amount of information in a few number of factors used in the VAR model. They use a large panel of data including 120 monthly US macroeconomic series covering the period from January 1959 to August 2001 and extract a few factors that summarize the information set contained in these series. In a VAR model, they employ these factors, along with the federal funds rate as a measure of monetary policy stance.

The central idea of the Factor Model (FM) is that information in a large data-set can be parsimoniously summarized by a small number of common factors. In recent years, large-dimensional dynamic factor models have become popular in empirical macroeconomics. They are more advantageous than other methods in various respects. FMs can cope with many variables without running into problems of scarce degrees of freedom often faced in regression-based analyses. Researchers and policy makers nowadays have more data at a more disaggregated level than ever before. Exploiting a lot of information can lead to more precise forecasts and macroeconomic analyses. A second advantage of factor models is that idiosyncratic movements which perhaps include measurement error and local shocks can be eliminated. This provides a more credible signal for policy makers and prevents them from reacting to idiosyncratic movements.

In addition to employing large amount of information in a model, the other advantage of FAVAR method is that we can potentially estimate the impulse response functions for all variables in the model. Thus, it allows us to see the impact of monetary policy on a wide range of macro-economic variables.

Belviso and Milani (B & M 2006) make the same argument as Bernanke et al. (2005) in support of the FAVAR model compared to a VAR model. However, they emphasize that the main shortcoming of FAVAR framework has been the inability to identify the factors which lack economic interpretation. Their solution to this drawback was to provide a structural
interpretation to the factors and assign a more immediate economic interpretation to each factor. They label this approach as structural factor-augmented vector autoregressive (SFAVAR) model. B & M (2006) divide a large dataset into several categories: real activity, inflation, interest rates, financial market, foreign, money, credit and expectations. Then they assume that each category, or segment, is explained by one factor. Finally, they estimate a real activity factor, an inflation factor, an interest rates factor, a financial market factor, a foreign factor, a money factor, a credit factor and an expectations factor. Therefore, the advantage of this approach over Bernanke et al.’s FAVAR model is that we can see the impact of monetary policy on the above economic segments in addition to each macroeconomic time series in the model.

There are some restrictions to B & M (2006) approach. First, the assignment of variables to various groups, which is basic for the interpretations of the factors, carries some element of arbitrariness. Second, the information set in each category may not be adequately captured by one factor. In case, we need two or more factors for some of these categories, this approach loses its advantage of summarizing broad information set by a few factors and we encounter the common problem of degrees of freedom in the estimation of the VAR equation in second step.

As we mentioned before, there has been limited research regarding the effects of monetary shocks on disaggregated prices. Bils, Klenow and Kryvtsov (2003) estimate the responses of 123 categories of overall consumer spending to a monetary policy shock by appending individual price series to a separately-estimated VAR. The VAR model involves non-farm employment, the consumption deflator, commodity prices, the nominal federal funds rate, non-borrowed reserves, total reserves, and M1. However, their estimated price responses display a price increase following an unexpected monetary policy tightening (price puzzle) - in sharp contrast to predictions of conventional models.

Nathan S. Balke and Mark A. Wynne (2007) document the response of the individual components of the Producer Price Index (PPI) to commonly used measures of monetary shocks, and show that these responses are at
variance with many widely-used “macro” models of monetary non-neutrality. To measure these shocks they employ a standard VAR methodology of the sort employed in Bils, Klenow and Kryvtsov (2003). They estimate a five-variable system consisting of industrial production, the personal consumption expenditures deflator, a commodity price index, the nominal federal funds rate and the M2 measure of the money stock. Monetary shocks are shown to have large relative price effects, resulting in an increase in the dispersion of the cross-section distribution of prices. Furthermore, in response to a contractionary (expansionary) monetary shock, a substantial number of prices tend to rise (fall). This suggests that the so-called “price puzzle” that is found in aggregate price indexes is present at the level of individual prices as well. Their findings complement the earlier findings of Bils, Klenow and Kryvtsov (2003) for components of the CPI and pose an important challenge for models of short run monetary non-neutrality.

Nakajima, Sudo and Tsuruga (2010) use a standard SVAR to estimate the impulse response functions of disaggregated prices to the monetary policy shocks. Based on the price data of US personal consumption expenditure, they find that disaggregated price responses have features across shocks and across sectors that are difficult to explain using standard multi-sector sticky price models. A substantial fraction of disaggregated prices initially rise in response to a contractionary monetary policy shock. The disaggregated price responses are correlated weakly with the frequency of price changes. They extend the standard model to reconcile these observations. They find that the cost channel of monetary policy and cross-sectional heterogeneity in real rigidity could pave the way for explaining these facts.

Although the articles mentioned above used VAR models to analyze the response of disaggregated prices, Haroon Mumtaz, Pawel Zabczyk and Colin Ellis (2009) use a factor-augmented vector auto regression technique to examine the role that macroeconomic and sector-specific factors play in UK price fluctuations at the aggregate and disaggregated levels. They conclude that Macroeconomic factors are less important for disaggregated prices than aggregated prices. There also appears to be significant aggregation bias — the persistence of aggregate inflation series is much higher than the
underlying persistence across the range of disaggregated price series. Their results suggest that monetary policy affects relative prices in the short to medium term, and that the degree of competition within industries plays a role in determining pricing behavior.

3. FAVAR Methodology

This section discusses the framework of the FAVAR methodology. As already mentioned, the limited information used in VAR models can result in some puzzles like price puzzle. One possible solution to the problem related to the limited information set in VAR models is adding a few factors that successfully summarize the information contained in many time-series variables.

We assume that $X_t$ is an $(N \times 1)$ vector of macroeconomic time series that contains information about the different sectors of the economy. Let $Y_t$ be an $(M \times 1)$ vector of observable time series of economic variables considered usually in VAR models for monetary policy analysis and assumed to have pervasive effects on the economy. $Y_t$ might include policy variables as well as observable measures of real activity and prices. $Y$ contains monetary base growth rate (it is expected that monetary base growth has a pervasive effect on the economy due to the importance of this variable in determining the rate of inflation in country). In most cases, standard VAR models use only these observable measures summarized by four to eight variables. One of the problems of this standard approach is that $Y_t$ cannot cover the same information set as $X_t$. Also, in standard VAR models that contain difference stationary variables, co-integration between non stationary variables should be considered. However in FAVAR models, the co-integration between factors isn’t expected due to the orthogonality factors.

We assume that the vector of $X_t$ can be represented as a linear combination of the $(K \times 1)$ vector of unobservable factors $F_t$. Assume that most of the information set contained in $X_t$ can be effectively summarized by a few unobserved factors as follows:
where $F$ is a $(K \times 1)$ vector of unobserved dynamic factors. $F$ can also represent theoretical concepts such as price pressures or economic activity that are a combination of economic variables which cannot be represented by one particular series.

The idea behind the factor models is that the economy is driven by a few common factors and idiosyncratic errors (Favero et al., 2005). Following Stock and Watson (2005), and Favero et al. (2005), the dynamic factor model expresses $Y_t$ as a distributed lag of a small number of unobserved factors and idiosyncratic error that are allowed to be serially correlate

$$Y_t = \lambda(L)F_t + u_t \quad (2)$$

$$u_t = \delta(L)u_{t-1} + \nu_t \quad (3)$$

where $F_t$ is a $(K \times 1)$ vector of unobserved dynamic factors, $\lambda$ $(L)$ is an $(M \times K)$ vector of factor loadings and $\nu_t$ is a white noise process. Also assume that factors and disturbances are not correlated or $E(F_t u_s) = 0, \forall t, s.$

From equation (3), $u_t = [I - \delta(L)L]^{-1}\nu_t$

Therefore, by replacing in equation 2, we have:

$$Y_t = \Lambda(L)F_t + \delta(L)Y_{t-1} + \nu_t \quad (4)$$

In above equation, $\Lambda(L) = [1 - \delta(L)L]\lambda(L)$.

On the other hand, we assume that the dynamics of factor is expressed by the following equation:

$$F_t = \Phi(L)F_{t-1} + \eta_t \quad (5)$$
where \( \eta_t \) is a \((k \times 1)\) vector of error terms.

By substituting the equation (5) into equation (4) and sorting it, equation (6) is obtained:

\[
Y_t = \Lambda(L)\Phi(L)F_{t-1} + \delta(L)Y_{t-1} + \omega_t
\]  

(6)

where, \( \omega_t \) equals \( \Lambda(L)\eta_t + \nu_t \)

FAVAR model is obtained by combining the equation (5) and (6).

\[
\begin{bmatrix}
F_t \\
Y_t
\end{bmatrix}
= \begin{bmatrix}
\Phi(L) & 0 \\
\Lambda(L)\Phi(L) & \delta(L)
\end{bmatrix}
\begin{bmatrix}
F_{t-1} \\
Y_{t-1}
\end{bmatrix}
+ \begin{bmatrix}
\eta_t \\
\omega_t
\end{bmatrix}
\]

(7)

Note that if the terms in \( \Phi(L) \) are all zero, the above system diminishes to a standard VAR. Therefore, using a standard VAR model leads to omitted variable bias, if the accurate system is FAVAR. Moreover, due to the fact that FAVAR nests the VAR model, we can easily compare these two models.

4. Data

The data for this study is taken from the central bank of Iran and International Financial Statistics. The data set used in the estimation of our FAVAR is a balanced panel of 96 quarterly series for the period running from 1990:01 to 2008:03\(^1\). The estimation period depends on data availability that varies across variables. The variables are selected from the following categories: real activity measures (such as GDP, consumption and investment), employment and wages, price indices, money and credit, foreign exchange rate, construction and housing, stock market, and the external sector. These variables contain useful information about the state of the economy and also help us with the appropriate identification of monetary policy shocks.

As we already mentioned, we are interested in the responses of the disaggregated price series to monetary shocks. To examine the effect of monetary shocks on disaggregated prices, we also collected data on 12 main categories of CPI. The details of all the series in the data set are described in the appendix.

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\(^1\) Real activity data has not been announced by central bank of Iran since the third quarter of 2008.
Due to the unavailability of quarterly data on some important variables, we use proportional Denton method for constructing quarterly series from annual series. We also remove the cyclical seasonal movements from series by implementing a seasonal adjustment method. All variables, with the exception of budget deficit, are transformed into logs and differentiated to get stationary time series - if necessary. These transformations were carried out on the basis of unit root tests, both Augmented Dickey-fuller and Philips-Peron. Since the different scales of the time series variables could impair factor extraction, all series were standardized to have a zero mean and a variance of one. The appendix describes the series as well as their sources and transformations in more details.

5. Bayesian Estimation of FAVAR

We estimate the model by using a Bayesian approach similar to Bernanke, Boivin, and Eliasz (2005) and Boivin, Giannoni, and Mihov (2009). This is a “one-step” estimation technique where factors are extracted and the VAR is estimated simultaneously. We apply a Gibbs sampling algorithm which approximates the posterior distribution (for more details about the Gibbs sampling algorithm see Bernanke, Boivin, and Eliasz (2005) appendix). Gibbs sampling is an example of Markov Chain Monte Carlo algorithm (MCMC). In order to apply Gibbs sampling method, we have to transform the model into a state space representation as follows:

$$\begin{bmatrix} X_t \\ Y_t \end{bmatrix} = \begin{bmatrix} \Lambda^f \\ 0 \end{bmatrix} \begin{bmatrix} F_t \\ 0 \end{bmatrix} + \begin{bmatrix} e_t \\ 0 \end{bmatrix} \quad \text{measurement equation (8)}$$

1. We use Census X11 adjustment method for removing the seasonal component of time series.
2. The other approach is a two-step principal component method. In the first step, we extract principal components from the large data set $X$, to obtain consistent estimates of the common factors. In the second step, we add monetary base growth rate and estimate a VAR model. The results from both estimation techniques are generally similar (Bernanke et al., 2005).
3. For estimating the model, we use MATLAB Code written by Gary Koop and Dimitris Korobilis. This code is downloadable from, http://personal.strath.ac.uk/gary.koop/bayes_matlab_code_by_koop_and_korobilis.html
The Effect of Monetary Shocks on …

\[
\begin{bmatrix}
F_t \\
Y_t
\end{bmatrix} = \Phi(L) \begin{bmatrix}
F_{t-1} \\
Y_{t-1}
\end{bmatrix} + \nu_t \quad \text{transition equation} \quad (9)
\]

It is assumed that \(e_t\) and \(\nu_t\) are normally distributed with zero mean and \(R\) and \(Q\) variances, \(e_t \sim N(0, R), \nu_t \sim N(0, Q)\). Moreover, these two error terms are independent and \(R\) is a diagonal matrix. Note that we enter \(Y_t\) in both equation of the state space system just for notational and computational simplification.

Parameters of the model are shown by the vector \(\theta = (\Lambda^f, R, \text{vec}(\Phi), Q)\), where \(\text{vec}(\Phi)\) is the column vector of the elements of the stacked matrix \(\Phi\) of the parameters of the lag operator \((L)\). Unlike the classical analysis, in the Bayesian approach, parameters are considered as random variables.

By defining the \(X_t = (\hat{X}_t, \hat{Y}_t)'\), \(e_t = (\hat{e}_t, 0, ..., 0)'\) and \(F_t = (\hat{F}_t, \hat{Y}_t)\), we can rewrite the state space system as follows:

\[
X_t = \Lambda F_t + e_t \quad (10)
\]

\[
F_t = \Phi(L)F_{t-1} + \nu_t \quad (11)
\]

By defining the sequence of \(X\) and \(F\) from period 1 to period \(T\) as \(\bar{F}_T = (F_1, F_2, ..., F_T)\) and \(\bar{X}_T = (X_1, X_2, ..., X_T)\), our problem is to characterize the marginal posterior densities of \(\bar{F}_T\) and \(\theta\). Below, we mention the basic four steps of this algorithm briefly:

1. **Selecting the starting parameter values** \((\theta^0)\). In this study, we choose parameter estimates obtained from principal components estimation of \((8)\) and the vector auto regression \((9)\) as starting values for \(\theta\). We also try different starting values and test if they all represent the same target distribution or not. Based on our MATLAB output, the algorithm is not sensitive to starting values.

2. **Generating a draw of factors, conditional on \(\theta^0\) and data.** Based on the knowledge of the conditional distributions which is necessary for implementing Gibbs sampling algorithm, we can sample factors from \(p(\bar{F}_T|\bar{X}_T, \theta^0)\). In this step, we use the Markov property of state space models and Kalman filter in order to sample from the conditional distribution.

---

1. For more details see Bernanke et al., 2005 and Eliasz (2002).
3. Generating a Draw of Parameters, Conditional on the Sampled Factors and Data. In order to sample from \( p(\theta | \bar{X}_T, \bar{F}_T) \) we need to divide parameters (\( \theta \)) into two parts: parameters of the observation equation (\( \Lambda, R \)); parameters of state equation (\( \text{vec}(\Phi), Q \)). For both parts of parameters, we assume conjugate priors (Bernanke et al., 2005). We choose diffuse Inverse-Gamma prior for \( R \) and Normal-Wishart prior for \( Q \).

4. Repeating Steps 2 and 3 Until the Algorithm Converges

The empirical marginal distributions of the factors and parameters are constructed from draws obtained after the algorithm had converged. The number of replications that we use in Gibbs sampling is 15,000. We discard the first 10,000 as burn-in. This number of replication is selected according to convergence assessment of the posterior moments. The point estimators of parameters and the factors and the confidence intervals are obtained by calculating the median values of the empirical distributions. The confidence intervals can be constructed from the empirical quantile.

5.1. Identification and Sampling Adequacy

We use the Cholesky identification method as Bernanke, Boivin, and Eliasz (2005) and Boivin, Giannoni and Mihov (2007). We assume that the unanticipated shocks to growth rate of monetary base affects the common factors, real GDP growth, inflation and exchange rate with a lag. In contrast, the monetary base growth rate is allowed to respond to shocks in all other variables immediately. We order the money base growth rate last and treat its innovations as monetary shocks, in the standard way. This ordering imposes the identifying assumption that the latent factors do not respond to monetary innovations within the quarter.

Other identification schemes like long run restriction (Blanchard and Quah, 1989) or structural VAR (Bernanke and Mihov, 1998) can be used in FAVAR modeling. However, these schemes require that the factors have economic interpretations.

Before conducting factor analysis, it is necessary to test the adequacy of sampling. There are two types of statistics that help to assess the adequacy of the correlation matrices for factor analysis. The Kaiser-Meyer-Olkin measure
of sampling adequacy tests whether the partial correlations among variables are small. The KMO should be greater than 0.5 for a satisfactory factor analysis to proceed. Large values for the KMO measure indicate that a factor analysis of the variables is a good idea. Looking at the table (1), the KMO measure is 0.72 and indicates that the number of variables is adequate for factor analysis. Another indicator of the strength of the relationship among variables is Bartlett's test of sphericity. Bartlett's test of sphericity is used to test the null hypothesis that the variables in the population correlation matrix are uncorrelated (the correlation matrix is an identity matrix). According to table (1), the observed significance level is .0000. It is small enough to reject the hypothesis. It is concluded that the relationship among the variables is strong and it is a good idea to proceed with a factor analysis for the data.

Table 1: Measures of KMO and Bartlett Test

<table>
<thead>
<tr>
<th>KMO and Bartlett's Test</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaiser-Meyer-Olkin Measure of Sampling Adequacy</td>
<td>.720</td>
</tr>
<tr>
<td>Bartlett's Test of Sphericity</td>
<td>Approx. Chi-Square</td>
</tr>
<tr>
<td></td>
<td>Sig.</td>
</tr>
</tbody>
</table>

Source: Research calculations (SPSS program)

5.2. Explanatory Power of the Factors

Table (2) reports the fraction of the variance explained by the common factors. According to table 2, the first factor with the largest eigenvalues explained about 20% of the variability of set X. The five factors explained more than 50% of the total variance. Note that, in some applications (typically in psychological or sociological studies) two or three factors explain more than 90 percent of the variables, while in macroeconomic panels a variance ratio of 40 percent is sometimes considered as a reasonable fit (Breitung and Eickmeie, 2005). Low explanatory power represented in Table (2) may be due to the lack of quarterly data for many important variables, such as sectoral employment and existence of missing data for a
number of economic variables such as construction and housing sectors especially in war time period.

Table 2: Cumulative Proportion of the Variability Explained by the Factors

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variance Proportion</td>
<td>19.653</td>
<td>11.217</td>
<td>8.32</td>
<td>7.23</td>
<td>6.17</td>
<td>4.54</td>
<td>4.244</td>
<td>3.55</td>
<td>3.37</td>
<td>2.85</td>
</tr>
<tr>
<td>Cumulative Variance</td>
<td>19.653</td>
<td>30.87</td>
<td>39.19</td>
<td>46.42</td>
<td>52.59</td>
<td>57.13</td>
<td>61.374</td>
<td>64.924</td>
<td>68.294</td>
<td>71.144</td>
</tr>
</tbody>
</table>

Source: Calculation by the authors (SPSS program)

5.3. Specifying the Number of Factors

In practice, the number of factors necessary to represent the correlation among the variables is usually unknown. To determine the number of factors empirically a number of criteria were suggested. For the approximate factor model Bai and Ng (2002) have suggested information criteria that can be used to estimate the number of factors.

The number of factors can be obtained using Bai-Ng information criteria ICp1 and ICp2. These criteria are very similar to well-known Akaike and Schwartz information criteria. Each of these criteria trades off goodness of fit versus the number of factors:

\[ IC_{p1}(k) = \ln \left( V(k, \hat{F}^k) \right) + k \left( \frac{N + T}{NT} \right) \ln \left( \frac{NT}{N + T} \right) \]  

(12)

\[ IC_{p2}(k) = \ln \left( V(k, \hat{F}^k) \right) + k \left( \frac{N + T}{NT} \right) \ln \left( C_{NT}^2 \right) \]  

(13)

Let \( N, T, K \) be the number of variables, observations and factors. \( C_{NT}^2 = \min\{N, T\} \) and \( k = 1, \ldots, k_{\max} \) and

\[ \ln \left( V(k, \hat{F}^k) \right) = \min \frac{1}{NT} \sum_{i=1}^{N} \sum_{t=1}^{T} (X_{it} - \lambda_i^k F_t^k)^2 \]  

(14)

We should choose \( k \) that minimizes ICp1 and/or ICp2. Bai and Ng prove that specific forms of the penalty term give consistent estimates of \( k \). With \( k \) known, one can estimate factors \( F_t \) as first \( k \) principal components of data and
estimate FAVAR as discussed above. Based on first and second criterion respectively 2 and 3 factors are selected.

5.4. Specifying the Lag Length of the Model

The selected FAVAR model in this paper includes monetary base growth, GDP growth rate, inflation and exchange rate (non-official rate) as well as three factors. We use lag length criteria and also residual tests in order to specify the optimal lag. According to table (3), the model should include 2 lags.

Table 3: VAR Lag Order Selection Criteria

<table>
<thead>
<tr>
<th>HQ</th>
<th>SC</th>
<th>AIC</th>
<th>FPE</th>
<th>LR</th>
<th>Log</th>
<th>Lag</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.13047</td>
<td>11.21303</td>
<td>11.07696</td>
<td>0.759920</td>
<td>NA</td>
<td>-344.9241</td>
<td>0</td>
</tr>
<tr>
<td>10.23032</td>
<td>10.64309*</td>
<td>9.962733</td>
<td>0.249714</td>
<td>94.08522</td>
<td>-293.8261</td>
<td>1</td>
</tr>
<tr>
<td>10.05201*</td>
<td>10.79500</td>
<td>9.570349*</td>
<td>0.169774*</td>
<td>48.61730*</td>
<td>-265.4660</td>
<td>2</td>
</tr>
<tr>
<td>10.50496</td>
<td>11.57817</td>
<td>9.809232</td>
<td>0.219100</td>
<td>13.45266</td>
<td>-256.9908</td>
<td>3</td>
</tr>
<tr>
<td>11.03356</td>
<td>12.43698</td>
<td>10.12376</td>
<td>0.309456</td>
<td>8.896865</td>
<td>-250.8984</td>
<td>4</td>
</tr>
<tr>
<td>11.22451</td>
<td>12.95815</td>
<td>10.10064</td>
<td>0.318241</td>
<td>22.30432</td>
<td>-234.1702</td>
<td>5</td>
</tr>
<tr>
<td>11.53829</td>
<td>13.60215</td>
<td>10.20035</td>
<td>0.380312</td>
<td>15.51279</td>
<td>-221.3109</td>
<td>6</td>
</tr>
</tbody>
</table>

Source: researcher calculations

6. Examining the Sources of Fluctuations in Disaggregated Prices

The FAVAR framework allows us to analyze the sources of fluctuations in inflation rates of 12 main categories of CPI. In other words, the FAVAR allows us to examine the extent to which disaggregated inflations reflect either common or sector specific factors.

For this reason, for all inflation series, we consider the following equation:

$$\pi_{it} = \lambda_i C_t + e_{it}$$  \hspace{1cm} (15)

$$C_t = \begin{bmatrix} F_t \\ Y_t \end{bmatrix}$$
\( \pi_{it} \) includes the quarterly log difference in the respective price series. By means of this formula, we can distinguish the fluctuations caused by common factor (\( C_t \)) from those caused by sector specific shocks (\( e_{it} \)).

### 6.1. Volatility and Persistence of Aggregate and Disaggregate Inflation

In this section we examine the volatility and the persistence of aggregate and disaggregated quarterly inflation series. For evaluating the degree of persistence, for each inflation series and each of its components namely the common factors and the sector-specific components (measured using residuals), we estimate an autoregressive process of the following form\(^1\)

\[
\omega_t = \rho(L) \omega_{t-1} + \varepsilon_t
\]

The degree of persistence is obtained by the sum of the coefficients on all lags. In table 4 we report the statistics about the volatility and persistence of inflation series (both aggregate and disaggregate).

<table>
<thead>
<tr>
<th>Description</th>
<th>( R^2 )</th>
<th>Standard deviation</th>
<th>persistence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>common component</td>
<td>sector-specific</td>
</tr>
<tr>
<td></td>
<td></td>
<td>inflation</td>
<td>component</td>
</tr>
<tr>
<td>Aggregate inflation series</td>
<td></td>
<td>0.943</td>
<td>0.315</td>
</tr>
<tr>
<td>CPI</td>
<td>0.89</td>
<td>0.901</td>
<td>0.437</td>
</tr>
<tr>
<td>commodity</td>
<td>0.809</td>
<td>0.7</td>
<td>0.721</td>
</tr>
<tr>
<td>service</td>
<td>0.485</td>
<td>0.668</td>
<td>0.677</td>
</tr>
<tr>
<td>inflation series of 12 main categories of CPI</td>
<td></td>
<td>0.659</td>
<td>0.686</td>
</tr>
<tr>
<td>average</td>
<td>0.515</td>
<td>0.726</td>
<td>0.628</td>
</tr>
<tr>
<td>weighted average</td>
<td>0.492</td>
<td>0.261</td>
<td>0.383</td>
</tr>
<tr>
<td>median</td>
<td>0.599</td>
<td>0.884</td>
<td>0.971</td>
</tr>
<tr>
<td>minimum</td>
<td>0.067</td>
<td>0.218</td>
<td>0.179</td>
</tr>
</tbody>
</table>

Table 4: Volatility and Persistence of Inflation Series

Source: research calculations

---

1. On the basis of correlogram, Akaike and Schwartz information criteria, and also \( R^2 \) and Adjusted \( R^2 \), we choose 4 lags for this autoregressive process.
According to table (4), the average of $R^2$ for disaggregated inflation is 0.515 which indicates that about half of the fluctuation in disaggregated inflations is due to the sector specific innovations.

We find that the greater part of the volatility in aggregate inflation rates is due to fluctuations in the common components. (Note that sector specific factors play an important role in service inflation fluctuations).

However, disaggregated inflation volatility is more commonly due to sector-specific factors, rather than the common factors. We can see from table 4 that there is a substantial heterogeneity among the 12 categories of CPI.

There is a noticeable difference in the persistence of the series. We find that the aggregate inflation measure displayed a high degree of persistence, but the disaggregated series exhibited far less persistence. This means that the persistence of the aggregate CPI inflation is not the weighted average inflation persistence of 12 main categories. Therefore, results reflect the aggregation bias (the persistence of aggregate inflation series is much higher than the underlying persistence across the range of disaggregated price series).

As Imbset et al. (2005) argue that aggregate measures of persistence will be biased when there is heterogeneity in persistence among the disaggregated components. Specially, aggregate estimates of persistence will be higher than the average persistence of the underlying disaggregated series (upward bias).

According to the fact that different prices do not behave in a similar way as aggregate indices, employing an aggregate inflation measure to assess the behavior of prices or price-setting at the microeconomic level might be deceptive.

In addition, common factors are important in determining persistence for both aggregate and disaggregated series. However, common factors (such as activity or policy) are less important for disaggregated inflation than aggregate inflation due to the fact that disaggregated prices display generally less persistence.
7. Estimation Results

7.1. The Impulse Response Functions of Aggregate Inflation (VAR-FAVAR Comparison)

One way to assess the advantages of considering broader information is to compare the results obtained using FAVAR with those obtained using small-scale VAR.

Figures (1) and (2) show the responses of inflation to one standard deviation increase in monetary base growth rate in VAR and FAVAR models.

We compare the FAVAR results with those obtained in a small-scale standard VAR model. In doing so, we specify our VAR model in 4 variables (real GDP growth, inflation, growth rate of exchange rate (non-official rate) and money base growth rate). In VAR Model, inflation slightly decreases in reaction to a positive monetary shock. Therefore, there is evidence of a price puzzle in VAR model. After 2 quarters, inflation starts to increase and finally the impact of monetary shock disappears after passing 10 periods.

In figure (2) we can see that by augmenting VAR with common factors, there is no evidence of price puzzle. Thus, we can conclude that these factors
eliminate the omitted variable bias in VAR models. After passing 5 quarters, the effect of monetary shock on inflation reaches the maximum level and then gradually vanishes. Note that figure (2) reports the impulse response of inflation in standard deviation units.\(^1\)

When comparing the FAVAR model with the standard VAR, we observe that there is a quantitative change in the response of the inflation to monetary shock in FAVAR model (\(\%0.25\) versus \(\%0.15\) in fifth quarter). We conclude that the marginal contribution of the information regarding the factors was rather high.

### 7.2. Examining the Impulse Response Functions of Disaggregated Prices (12 main categories of CPI)

As we have discussed, an advantage of the FAVAR approach is that impulse response functions can be constructed for any variable in the informational data set, that is, for any element of \(X\).

Let \(P_i\) be the (log) price index for category \(i\). The response of \((P_i)\) to monetary shock is obtained from the following equation:

\[
\frac{\partial P_{it+j}}{\partial MB_t} = \lambda_{i,1} \frac{\partial \widehat{F}_{1t+j}}{\partial MB_t} + \lambda_{i,2} \frac{\partial \widehat{F}_{2t+j}}{\partial MB_t} + \cdots + \lambda_{i,k} \frac{\partial \widehat{F}_{kt+j}}{\partial MB_t}
\]

(17)

where \(\frac{\partial \widehat{F}_{kt+j}}{\partial MB_t}\) is the response of estimated factor \(k\) to a monetary shock in \(j\) periods ahead; \(\lambda_i\)'s are factor loadings. We use MATLAB program for estimating and obtaining the impulse response functions of variables of interest.

In this section, we describe the response of 12 main categories of CPI to a monetary shock, defined as an unexpected increase of the monetary base growth rate. Figure (3) shows the estimated impulse responses of disaggregated prices to an unexpected monetary shock. Since it is quite common in the monetary policy analysis based on FAVAR modeling to determine the confidence bands at 70\% [Lagana and Mountford (2005), Belviso and Milani (2006), Boivin and Giannoni (2008)] in Figure 3, the corresponding 70-percent confidence intervals (dashed lines) are calculated.

---

1. The standard deviation of inflation in the period under review is about two percent.
**Figure 3: Estimated Impulse Response of 12 Main Categories of CPI to an Increase in Money Base Growth Rate Estimated by Gibbs Sampling** (In standard deviation units)**

<table>
<thead>
<tr>
<th>Category</th>
<th>Graph 1</th>
<th>Graph 2</th>
<th>Graph 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPIf</td>
<td><img src="image1" alt="Graph" /></td>
<td><img src="image2" alt="Graph" /></td>
<td><img src="image3" alt="Graph" /></td>
</tr>
<tr>
<td>CPItob</td>
<td><img src="image4" alt="Graph" /></td>
<td><img src="image5" alt="Graph" /></td>
<td><img src="image6" alt="Graph" /></td>
</tr>
<tr>
<td>CPIclo</td>
<td><img src="image7" alt="Graph" /></td>
<td><img src="image8" alt="Graph" /></td>
<td><img src="image9" alt="Graph" /></td>
</tr>
<tr>
<td>CPIh</td>
<td><img src="image10" alt="Graph" /></td>
<td><img src="image11" alt="Graph" /></td>
<td><img src="image12" alt="Graph" /></td>
</tr>
<tr>
<td>CIPFur</td>
<td><img src="image13" alt="Graph" /></td>
<td><img src="image14" alt="Graph" /></td>
<td><img src="image15" alt="Graph" /></td>
</tr>
<tr>
<td>CIPcmm</td>
<td><img src="image16" alt="Graph" /></td>
<td><img src="image17" alt="Graph" /></td>
<td><img src="image18" alt="Graph" /></td>
</tr>
<tr>
<td>CPIcomm</td>
<td><img src="image19" alt="Graph" /></td>
<td><img src="image20" alt="Graph" /></td>
<td><img src="image21" alt="Graph" /></td>
</tr>
<tr>
<td>CPIrest</td>
<td><img src="image22" alt="Graph" /></td>
<td><img src="image23" alt="Graph" /></td>
<td><img src="image24" alt="Graph" /></td>
</tr>
<tr>
<td>CPIedu</td>
<td><img src="image25" alt="Graph" /></td>
<td><img src="image26" alt="Graph" /></td>
<td><img src="image27" alt="Graph" /></td>
</tr>
<tr>
<td>CPIoth</td>
<td><img src="image28" alt="Graph" /></td>
<td><img src="image29" alt="Graph" /></td>
<td><img src="image30" alt="Graph" /></td>
</tr>
</tbody>
</table>

1 Standard deviation of first difference of price of 12 main categories (cpi; cpitob; cpielo; cpih; cpifur; cpiomm; cpiitr; cpioth; cpi; cpiedu; cpi; cpioth) are respectively 3.5, 6.4, 3.2, 1.6, 3.1, 2.8, 3.4, 5.8, 4.5, 4.7, 2.4, 2.3 percentage.

*CPIf: food and beverages; tob: tobacco; clo: clothing and footwear; h: housing, water, fuel and power; fur: household furnishing and operations; comm: communication; tran: transportation; med: medical care; rest: restaurant and hotels; edu: education; ent: entertainment; oth: miscellaneous goods and services.

**Note that the impulse responses report in standard deviation units**
We observe some heterogeneity in the response patterns. A noticeable result is that the magnitude of response for most categories is quite small in the initial quarters after the monetary shock and begins to increase gradually later. According to Figure 3 and standard deviation of 12 main categories of CPI, we can see that a positive monetary shock has a considerable effect on entertainment, clothing and footwear, household furnishing and operations, tobacco and miscellaneous goods and services respectively; while monetary shocks have a limited effect on education and medical care. Based on the number of periods after which the disaggregated prices respond to monetary shock, the sub-categories of CPI can be compared in terms of the degree of price stickiness. The results show that education, communication, medical care, transaction and housing, water, fuel and power have a relatively high degree of price stickiness. These features in the data can be explained by a multi-sector sticky price models. The multi-sector sticky price model predicts that frequently adjusted prices should respond more quickly to macroeconomic shocks than infrequently adjusted prices.

A relatively high degree of price stickiness observed in education, communication, medical care, transaction and housing, water, fuel and power categories can be attributed to the nature of price setting in these sectors. Generally speaking, prices in these sectors are often determined by government which, at least in our sample period, has not been willing to adjust prices frequently or change price by large adjustments. Due to the fact that government-owned entities account for a significant share of activities in these sectors, there is a significant degree of price control.

A positive monetary shock has a little effect on housing, water, fuel and power sectors in the first four quarters, reflecting a rather high degree of price stickiness. A positive monetary shock increases the price of this category gradually and after about 15 quarters, the effect of shock on housing category disappears.

According to the classification of consumer goods and services in Iran, housing, water, fuel and power category contains “rental equivalence of owner occupied houses”, “rent of residential houses”, “maintenance and repair services”, water, fuel and power. Considering the fact that prices of
water, fuel and power set administratively in Iran, it is better to examine the effects of monetary shocks on other sub-categories. Therefore, due to the importance of housing category in consumer price index (26.8% of CPI), we analyze the effect of an increase in monetary base growth rate on housing (which includes “rental equivalence of owner occupied houses”, “rent of residential houses” and “maintenance and repair services”). Figure (4) shows the responses of housing sub-categories to an increase in money base growth rate. As we can see from figure (4), the impulse response function of “Housing” sub-category to a positive monetary shock is approximately the same as CPIH in figure (3). Since prices of water, fuel and power are set by government; therefore, a positive monetary shock only affects the housing component in the “housing, water, fuel and power” category.

**Figure 4: Estimated Impulse Response of Housing to an Increase in Money Base Growth Rate**

![Impulse Response of Housing category](image)

7.2. Results of Robustness Tests

We check for robustness in three ways. First, we check the robustness of our results with respect to the number of factors included in the FAVAR specification. Second, we check for robustness with respect to different specifications of VAR equation. Third, we change the arrangement of variable in Cholesky identification in order to examine the robustness of our results.

Through examination of the impulse responses for different number of factors, we find out that the results are robust to the number of factors. In addition, based on Bernanke et al. (2005) and Mumtaz et al. (2009), we can
specify our model in a way that monetary base growth rate is the only observable variable and the other three variables (GDP growth rate, inflation and exchange rate) along with the other series in data set are used to extract factors. Thus, VAR equations include monetary base growth rate (reflecting the monetary stance) and three other factors. The results from this specification indicates that there is no significant difference in the impulse response functions of disaggregated prices in comparison to the first specification (as mentioned before, the model includes monetary base growth, GDP growth rate, inflation and exchange rate (non-official rate) as well as three factors). Finally, by examining the impulse responses of disaggregated prices for different arrangement of variable in Cholesky identification, we find out that the results are robust to these changes and there is not a significant change in their response to monetary shock.

8. Conclusion

In this paper, we utilized FAVAR approach proposed by Bernanke et al. (2005) in order to examine the effect of monetary shocks on disaggregated price indices. This framework permits the possibility of including all relevant macroeconomic time series and generates impulse response functions for all these variables. Moreover, by using this method we are able to match the information set available to the monetary authorities as much as possible. As Aoki (2001) argues the aggregate inflation may not display properly the dynamics and pricing behavior at the micro level. This means that the behavior of disaggregated prices can be substantially different from the aggregated price index. It is possible to observe the different dynamics of consumer goods and services prices which help us to improve our understanding of the monetary transmission mechanism at the micro level.

Three main findings of this paper are summarized as follows: First, monetary shocks have a delayed effect on disaggregated prices. Most sub-categories of CPI react to monetary shocks with a significant delay. Impulse response functions obtained from VAR models do not display price rigidities well. In such a model, a positive monetary shock causes an increase in the price index of all categories after one quarter. However, in the FAVAR
framework used in this paper, considerable rigidities of prices are observable. Most of the categories of CPI react to monetary shock after at least 4 quarters. Second, there is a substantial difference between 12 categories in response to an increase in money base growth rate. Finally, according to the impulse response function of 12 categories, there is no evidence of a price puzzle, as opposed to existing studies based on standard VAR models.

The new information obtained in this paper which is useful for monetary policy makers is to take into account the difference in degree of rigidities among 12 categories and also delayed effect of monetary shocks on disaggregated prices. Thus, awareness of heterogeneous effect of monetary policy on disaggregated prices is essential for policy makers.
References


## Appendix (1)
### List of Variables Used in the Study

<table>
<thead>
<tr>
<th>No.</th>
<th>variables</th>
<th>Abbr.</th>
<th>source</th>
<th>unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>output, consumption and investment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>value-added of agricultural group (at constant prices)</td>
<td>VAAGR</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>3</td>
<td>value-added of oil group (at constant prices)</td>
<td>VAOIL</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>4</td>
<td>value-added of manufacturing and mining group (at constant prices)</td>
<td>VIND</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>5</td>
<td>value-added of construction</td>
<td>VAHOS</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>6</td>
<td>value-added of electricity, gas and water (at constant prices)</td>
<td>VAW</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>7</td>
<td>value-added of service group (at constant prices)</td>
<td>VASER</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>8</td>
<td>value-added of trade, restaurant and hotel</td>
<td>VABUS</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>9</td>
<td>value-added of transportation, storage and communication</td>
<td>VATRA</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>10</td>
<td>value-added of financial and monetary institutions services</td>
<td>VAMON</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>11</td>
<td>value-added of real estate, specialized and professional services</td>
<td>VABUL</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>12</td>
<td>Industrial production index (1990=100)</td>
<td>IPI</td>
<td>CBI</td>
<td>-</td>
</tr>
<tr>
<td>13</td>
<td>electricity generation</td>
<td>PELEC</td>
<td>CBI</td>
<td>Million kilowatt hours</td>
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<tr>
<td>14</td>
<td>crude oil production</td>
<td>OILPRO</td>
<td>CBI</td>
<td>Thousand barrels per day</td>
</tr>
<tr>
<td>15</td>
<td>public consumption expenditure (at constant prices)</td>
<td>GOVCE</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>16</td>
<td>private consumption expenditure (at constant prices)</td>
<td>PCE</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>17</td>
<td>Domestic consumption of oil products</td>
<td>COIL</td>
<td>CBI</td>
<td>Thousand Barrels Per Day</td>
</tr>
<tr>
<td>18</td>
<td>Gross fixed capital formation (at constant prices)</td>
<td>TOTINV</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
</tbody>
</table>

1. Central Bank of Iran
<table>
<thead>
<tr>
<th>No.</th>
<th>variables</th>
<th>Abbr.</th>
<th>source</th>
<th>unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>Gross fixed capital formation in construction (at constant prices)</td>
<td>BUIINV</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>19</td>
<td>Gross fixed capital formation in machinery (at constant prices)</td>
<td>EQUINV</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>20</td>
<td>change in inventories</td>
<td>CII</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>21</td>
<td>Total employment</td>
<td>LL</td>
<td>PDSPC(^1)</td>
<td>person</td>
</tr>
<tr>
<td>22</td>
<td>employment in agricultural sector</td>
<td>LAGR</td>
<td>PDSPC</td>
<td>person</td>
</tr>
<tr>
<td>23</td>
<td>employment in manufacturing and mining sector</td>
<td>LIND</td>
<td>PDSPC</td>
<td>person</td>
</tr>
<tr>
<td>24</td>
<td>employment in electricity, gas and water sector</td>
<td>LWAT</td>
<td>PDSPC</td>
<td>person</td>
</tr>
<tr>
<td>25</td>
<td>employment in construction sector</td>
<td>LHOS</td>
<td>PDSPC</td>
<td>person</td>
</tr>
<tr>
<td>26</td>
<td>employment in trade, restaurant and hotel sector</td>
<td>LBIS</td>
<td>PDSPC</td>
<td>person</td>
</tr>
<tr>
<td>27</td>
<td>employment in transportation, storage and communication sector</td>
<td>LTRICT</td>
<td>PDSPC</td>
<td>person</td>
</tr>
<tr>
<td>28</td>
<td>employment in financial and monetary institutions services</td>
<td>LMON</td>
<td>PDSPC</td>
<td>person</td>
</tr>
<tr>
<td>29</td>
<td>employment in real estate, specialized and professional services sector</td>
<td>LPRO</td>
<td>PDSPC</td>
<td>person</td>
</tr>
<tr>
<td>30</td>
<td>employment in social, personal and household services sector</td>
<td>LOTRS</td>
<td>PDSPC</td>
<td>person</td>
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<tr>
<td>31</td>
<td>industrial employment index</td>
<td>EMPW</td>
<td>CBI</td>
<td>-</td>
</tr>
<tr>
<td>32</td>
<td>wage index of manufacturing workers (deflated by CPI)</td>
<td>RWI</td>
<td>CBI</td>
<td>-</td>
</tr>
<tr>
<td>33</td>
<td>wage index of an unskilled construction worker (deflated by CPI)</td>
<td>RBWWI</td>
<td>CBI</td>
<td>-</td>
</tr>
<tr>
<td>34</td>
<td>construction services index (deflated by CPI)</td>
<td>RBWI</td>
<td>CBI</td>
<td>-</td>
</tr>
</tbody>
</table>

price indices

| 35  | producer price index (1997=100)                                          | PPI   | CBI    | -                                         |
| 36  | PPI (agriculture, hunting, forestry and)                                  | PPIAG | CBI    | -                                         |

1. Deputy president, Strategic Planning and Control (Macroeconomic Office)
<table>
<thead>
<tr>
<th>No.</th>
<th>variables</th>
<th>Abbr.</th>
<th>source</th>
<th>unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>37</td>
<td>PPI (manufacturing)</td>
<td>PPII</td>
<td>CBI</td>
<td>-</td>
</tr>
<tr>
<td>38</td>
<td>PPI (services)</td>
<td>PPISER</td>
<td>CBI</td>
<td>-</td>
</tr>
<tr>
<td>39</td>
<td>CPI (food, beverages)</td>
<td>CPIF</td>
<td>CBI</td>
<td>-</td>
</tr>
<tr>
<td>40</td>
<td>CPI (tobacco)</td>
<td>CPITOB</td>
<td>CBI</td>
<td>-</td>
</tr>
<tr>
<td>41</td>
<td>CPI (clothing and footwear)</td>
<td>CPICLO</td>
<td>CBI</td>
<td>-</td>
</tr>
<tr>
<td>42</td>
<td>CPI (housing, water, fuel and power)</td>
<td>CPIH</td>
<td>CBI</td>
<td>-</td>
</tr>
<tr>
<td>43</td>
<td>CPI (rental equivalence of owner occupied houses)</td>
<td>REO</td>
<td>CBI</td>
<td>-</td>
</tr>
<tr>
<td>44</td>
<td>CPI (Rent of residential houses)</td>
<td>RRH</td>
<td>CBI</td>
<td>-</td>
</tr>
<tr>
<td>45</td>
<td>CPI (Maintenance and repair services)</td>
<td>MRS</td>
<td>CBI</td>
<td>-</td>
</tr>
<tr>
<td>46</td>
<td>CPI (household furnishings and operations)</td>
<td>CPIFUR</td>
<td>CBI</td>
<td>-</td>
</tr>
<tr>
<td>47</td>
<td>CPI (medical care)</td>
<td>CPIMED</td>
<td>CBI</td>
<td>-</td>
</tr>
<tr>
<td>48</td>
<td>CPI (transportation)</td>
<td>CPITRA</td>
<td>CBI</td>
<td>-</td>
</tr>
<tr>
<td>49</td>
<td>CPI (communication)</td>
<td>CPICOM</td>
<td>CBI</td>
<td>-</td>
</tr>
<tr>
<td>50</td>
<td>CPI (recreation)</td>
<td>CPIENT</td>
<td>CBI</td>
<td>-</td>
</tr>
<tr>
<td>51</td>
<td>CPI (education)</td>
<td>CPIEDU</td>
<td>CBI</td>
<td>-</td>
</tr>
<tr>
<td>52</td>
<td>CPI (hotel and restaurant)</td>
<td>CPIREST</td>
<td>CBI</td>
<td>-</td>
</tr>
<tr>
<td>53</td>
<td>CPI (miscellaneous goods and services)</td>
<td>CPIOTH</td>
<td>CBI</td>
<td>-</td>
</tr>
<tr>
<td>54</td>
<td>consumer price index (commodity)</td>
<td>CPICOM</td>
<td>CBI</td>
<td>-</td>
</tr>
<tr>
<td>55</td>
<td>consumer price index (services)</td>
<td>CPISER</td>
<td>CBI</td>
<td>-</td>
</tr>
<tr>
<td>56</td>
<td>GDP implicit index</td>
<td>GDPDEF</td>
<td>IFS</td>
<td>-</td>
</tr>
<tr>
<td>57</td>
<td>import price index</td>
<td>MPI</td>
<td>CBI</td>
<td>-</td>
</tr>
<tr>
<td>58</td>
<td>export price index</td>
<td>XPI</td>
<td>CBI</td>
<td>-</td>
</tr>
<tr>
<td>59</td>
<td>Iranian oil price</td>
<td>OILP</td>
<td>OPEC</td>
<td>Barrel - USD</td>
</tr>
<tr>
<td>60</td>
<td>residential square meter prices in Tehran</td>
<td>TEHOUP</td>
<td>MRUD!</td>
<td>Thousands Rials</td>
</tr>
<tr>
<td>61</td>
<td>monetary and credit aggregates</td>
<td>M0</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
</tbody>
</table>

1. Ministry of roads and urban developments

**Notes:**

* Securities and Exchange Organization.

** All variables regarding government budget and fiscal data are adjusted by appropriate indices. Therefore, the real amount of these variables is used in study.
<table>
<thead>
<tr>
<th>No.</th>
<th>variables</th>
<th>Abbr.</th>
<th>source</th>
<th>unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>62</td>
<td>money supply (M1)</td>
<td>M1</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>63</td>
<td>liquidity (M2)</td>
<td>M2</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>64</td>
<td>central bank claims on public sector</td>
<td>GDEBT</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>65</td>
<td>private sector deposits</td>
<td>PDEP</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>66</td>
<td>non demand deposit with banks and credit institutions</td>
<td>TSD</td>
<td>IFS</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>67</td>
<td>demand deposits</td>
<td>DDEP</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>68</td>
<td>depository institution reserves</td>
<td>TBR</td>
<td>IFS</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>69</td>
<td>required reserves of banks (banks legal deposit with central banks)</td>
<td>REQRES</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>70</td>
<td>excess reserves (banks sight deposit with central banks)</td>
<td>EXCRES</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>71</td>
<td>banking system claims on private sector</td>
<td>PCRT</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>72</td>
<td>current payments</td>
<td>RGEX</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>73</td>
<td>development payments</td>
<td>RGSTEX</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>74</td>
<td>budget deficit</td>
<td>DEFI</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>75</td>
<td>oil revenues</td>
<td>OILREV</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>76</td>
<td>Tax revenues</td>
<td>TAX</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>77</td>
<td>real effective exchange rate</td>
<td>REER</td>
<td>IFS</td>
<td>-</td>
</tr>
<tr>
<td>78</td>
<td>value of share trading</td>
<td>SP</td>
<td>SEO*</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>79</td>
<td>total share price index</td>
<td>SI</td>
<td>SEO</td>
<td>-</td>
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<tr>
<td>80</td>
<td>building starts by private sector in urban areas</td>
<td>HS</td>
<td>CBI</td>
<td>housing unit</td>
</tr>
<tr>
<td>81</td>
<td>building starts by private sector in large cities</td>
<td>HSM</td>
<td>CBI</td>
<td>housing unit</td>
</tr>
<tr>
<td>82</td>
<td>construction permits issued by municipalities in urban areas</td>
<td>HP</td>
<td>CBI</td>
<td>housing unit</td>
</tr>
<tr>
<td>83</td>
<td>construction permits issued by municipalities in large cities</td>
<td>HPM</td>
<td>CBI</td>
<td>housing unit</td>
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</table>
## Variables, Abbr., Source, and Unit

<table>
<thead>
<tr>
<th>No.</th>
<th>variables</th>
<th>Abbr.</th>
<th>source</th>
<th>unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>84</td>
<td>private sector investment in new building in urban areas</td>
<td>NBUL</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>85</td>
<td>private sector investment in building starts in urban areas</td>
<td>SBUL</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>86</td>
<td>private sector investment in semi-finished buildings in urban areas</td>
<td>HCBL</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>87</td>
<td>private sector investment in completed buildings in urban areas</td>
<td>CBL</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
</tbody>
</table>

### External sector

<table>
<thead>
<tr>
<th>No.</th>
<th>variables</th>
<th>Abbr.</th>
<th>source</th>
<th>unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>88</td>
<td>Imports of goods and services (at constant prices)</td>
<td>IM</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>89</td>
<td>Imports of capital goods (deflated by import price index)</td>
<td>IMCAP</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>90</td>
<td>Imports of raw materials and intermediate goods (deflated by import price index)</td>
<td>IMINT</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>91</td>
<td>Imports of consumer goods (deflated by import price index)</td>
<td>IMCON</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>92</td>
<td>exports of goods and services (at constant prices)</td>
<td>EX</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>93</td>
<td>non-oil exports (deflated by export price index)</td>
<td>EXPNO</td>
<td>CBI</td>
<td>Billion Rials</td>
</tr>
<tr>
<td>94</td>
<td>crude oil exports</td>
<td>OILEXP</td>
<td>CBI</td>
<td>Thousands of barrels per day</td>
</tr>
<tr>
<td>95</td>
<td>net capital account</td>
<td>CAPIT</td>
<td>CBI</td>
<td>million dollars</td>
</tr>
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</table>

### Expectations

<table>
<thead>
<tr>
<th>No.</th>
<th>variables</th>
<th>Abbr.</th>
<th>source</th>
<th>unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>96</td>
<td>expected inflation$^1$</td>
<td>FINRT</td>
<td>research computations</td>
<td>percentage</td>
</tr>
</tbody>
</table>

---

1. Note that in Iran there is no official data on expectation. Therefore, based on the theory of adaptive expectations and also significance of coefficients of lagged dependent variable (inflation), we consider the following formula for computing the expected inflation:

$$\inf_t = 0.011552 + 0.419 \inf_{t-1} + 0.3437\inf_{t-2}$$
Central Bank Transparency and Monetary Policy Effectiveness

Anton Comanescu* 

Abstract

The paper concentrates on the conditions, contingencies and determinants of central bank transparency and communication. From the state of the economy and the quality of national institutions, to the structure of monetary policy committees, the personality of the governor and the nature of the monetary policy framework - with a particular focus on the case of inflation targeting, there is a plethora of factors influencing the design and the conduct of a communication strategy. The debate remains open on whether we can speak about best practice or an optimal communication policy, but conflicting policy choices and outcomes seem to point to the fact that communication remains one of the greatest challenges for every central banker. The conclusion of the study is that there is no one-size-fits-all dogma for transparency. Cultural and national differences are paramount for choosing the best practice.

Keywords: Central Bank, Transparency, Communication

JEL Classification: E58, E61

* Dr. Anton Comanescu, City University of Seattle; Economist, National Bank of Romania
1. Some Preliminary Lessons from the Literature

As a process to convey messages in order to influence behavior, the fundamentals of communication are, to a large extent, intermingled with those of rhetoric. This perspective justifies a brief excursion in the evolution of the latter. In historical terms, there is a consensus that four major stages shaped rhetoric since antiquity until today. The first stage is rhetoric centered on the speaker and his performance, à la Cicero and Quintilian. In his De Oratore, Cicero advocates the so called ‘Asian’ style of emotional, rhythmical and ornate rhetoric. In Institutio Oratoria, that remained for centuries the reference text on rhetoric, Quintilian develops the principles of Cicero, and considers the speech an artistic product, a literary achievement in itself, beyond its persuasive and contextual value. This view can be traced back to Plato for whom rhetoric’s main function is to express philosophical truths, to find the right formula to materialize ideas. The second stage can be traced on the line of thought inaugurated by Aristotle, who shifts the focus from speaker to audience. For him, rhetoric is an art of doing not an art of making. A discourse is valuable to the extent to which it exerts a persuasive action on an audience. Unfortunately, ancient Rome did not elaborate significantly on this view, therefore rhetoric, public speaking and even literature (including religious texts) remained during Middle Ages and Renaissance rooted in Platonic ideals. A subsequent third stage emerges with the invention of the printing press that gradually places emphasis on content and impersonal transmission of information. The last stage, currently under development, is what is usually known as the new rhetoric that recuperates some of the Aristotelian perspective, in the sense that any communication, oral or written, has to be prepared with the audience in mind.

Economics, without following this historical pathway, absorbed communication issues in their Platonic form, being quite far from digesting the shift to the new rhetoric of Aristotelian extraction. The optimism associated with the belief that inflation targeting would succeed mainly
through communication to anchor expectations around the ‘Platonic’ idea that stable prices are beneficial for the economy, without considering the role of public perceptions, proved to be flawed. In many countries, adoption of inflation targeting lead to a change in the macroeconomic environment but did not create a regime change. Inflation targeting implies an observable policy regime, in Platonic terms it is the expression of a philosophical truth, but this expression of an idea fails to persuade the public in situations of uncertainty or financial instability. Furthermore, recent studies show that there is no clear consensus has emerged that inflation targeting is an efficient framework in curbing inflation and enhancing growth on the long run (Mishkin, 2004).

Central bankers could learn some lessons from political marketing. Between the historical opaqueness and the recent transparency qua mantra, there should be a third way for a modern central bank to convey important information to the public without running the fatal risk of being misunderstood or misperceived. If a finance minister is able to use media to better explain his fiscal plan and gain public support, monetary policy should benefit from media exposure in a similar way. The need to distance himself from political influence and the fear of losing credibility traditionally made the central banker a rather timid and ‘introverted’ policymaker. Bob Woodward offers an expressive image of Paul Volcker, former chairmen of the Fed:

“Privately, Volcker was a bit worried about the economy. He didn’t think there would be another recession very soon, but growth was slowing and the outlook wasn’t very good. His next action at the Fed was probably going to be exactly what Baker and Reagan wanted him to do, to ease up and lower interest rates. But he didn’t tell them that because he didn’t trust them. If he said anything, they would leak it to the press. Interest rates are going down, they’d say. Or worse, the Federal Reserve caved to their pressure, undermining Volker’s credibility.”

One can clearly notice from this account the inherent disclosure problem faced by the central banker, a problem that often leads to a policymaker’s
spiral of silence\textsuperscript{1} leveraging the public’s spiral of deafness. When monetary policy issues became sensitive and there was a clear need for ambiguity, the solution came naturally for a skilled communicator like Greenspan: “I’ll just say a little bit this way and a little bit that way, and I’ll completely confuse them so there’ll be no story.”\textsuperscript{2} Constructive ambiguity is a must when, for example, financial stability is at stake, as it was the case in the aftermath of the stock market crash in 1987 or the Lehman Brothers collapse in 2008. However, silence can create a vicious circle when it comes to the more common operations. The fear of losing credibility or creating misperceptions often turns central bankers too opaque, becoming prisoners of their own secretiveness. Therefore, when the public expects guidance, the policymaker prefers to remain silent, vague or even to lie. The same Greenspan, who wanted to confuse the press, realized that hiding obvious facts could prove fatal in autumn 1987.

“He particularly didn’t want anyone from the Fed to sound like Herbert Hoover, president in 1929, declaring with historically memorable stupidity after Black Tuesday that everything was terrific. Everything wasn’t terrific. They were in a real crisis. Failure to acknowledge even this simple state of reality would cause the knowledgeable players in the market to think the Fed ought to go to the loony bin.”\textsuperscript{3}

In such cases, the failure of the policymaker to explain the reality in a constructive manner, leads not only to his loss of reputation and credibility but also to a systematic disconnection between the public’s attentiveness and the policymaker’s discourse. More fundamentally, the result is a loss of social attention,\textsuperscript{4} as Shiller (2000) argues in his account of the irrational exuberance years. In his view, social attention is a contagious phenomenon.\textsuperscript{5} As there is a social basis for attention, individuals who recognize the importance

\textsuperscript{1} The original concept, coined by the German political scientist Elisabeth Noelle-Neumann, refers to the influence of public opinion on individual opinions and actions.
\textsuperscript{2} Woodward, (2000).
\textsuperscript{3} Ibid.
\textsuperscript{4} According to Shiller (2000), social attention is based on ‘socially based selectivity’.
\textsuperscript{5} In Shiller’s view “the social attention mechanism generates a sudden focus of the attention of the entire community on matters that appear to be emergencies. Thus, to return to the epidemic model, the infection rate may suddenly and dramatically increase. A sudden major move in the stock market is one of those events that pushes aside all other conversation.”
of some information bring it to the attention of other members of the community, thus creating a more homogenous view of the world within that community. Therefore, the likelihood of an event affecting market prices is higher if “there is a good, vivid, tellable story about the event”\(^1\) which will increase the rate of spread of the news.

Analyzing the role of media in the information processing by the public, Graber (2001) observes the discrepancy between the availability of important amounts of political information and the limited information-processing capacities of individuals, similarly with Baran and Davis’ (2009) ‘knowledge gap’. This gap is opening even further when people lose their attention and interest because of policymakers’ inability to present qualitative information, in an user-friendly manner, to stimulate ‘audience diligence’ in attending the information.\(^2\)

“When politics is pedestrian, when it becomes abstract and disconnected from people’s personal interests, they tune out. The sense of civic responsibility can be heightened if news presentations are gripping and user-friendly”\(^3\)

For their decision making processes, people either seek news that confer them confidence in their own worldviews, as Carnot et al. (2005) observe in their analysis of the impact of economic forecasts, or they need ‘news they can use’ (Graber, 2001), information that either triggers emotional responses or bears a clear practical utility for the audience.\(^4\) Particularly in times of uncertainty, the importance of practical information increases. After the stock market crash in 1987, the need to send a clear and loud message about the readiness of the Fed to react swiftly was crucial. Gerald Corrigan, president of the New York Fed, was pointing out in a meeting of the Greenspan’s FOMC: “We don’t need a scholarly, legalistic thing. We’ve just got to say in one sentence, we’re going to put a lot of money in the market.”\(^5\)

\(^1\) Shiller (2000).
\(^2\) The concept of user-friendly information in its very practical sense has been recently materialized by many central banks in their overhauling of websites that offer information about monetary policy objectives and operations in a clearer and gripping manner.
\(^3\) Graber (2001).
\(^4\) One of the most visible trends in this respect is the development of health or travel programs and sections in the media, marking a clear departure from the hard topics about government policies.
\(^5\) Quoted by Woodward (2000).
In an attempt to calm down the markets, President Ronald Reagan wanted Greenspan to deliver a speech to an audience of bankers in Dallas, to convey a sense of business as usual. Learning the lesson from the Black Tuesday crash of October 29, 1929 and from president Hoover’s deadly mistake, Greenspan realized that “a routine speech to bankers in the midst of an obvious crisis would send a signal that the chairman was out of touch with reality. Greenspan cancelled his speech” and returned to Washington to issue a one-sentence statement in his name, before the markets opened:

“The Federal Reserve, consistent with its responsibilities as the nation’s central bank, affirmed today its readiness to serve as a source of liquidity to support the economic and financial system.”

The statement was soon backed by the Treasury Secretary Jim Baker, who considered it brilliant, and helped the Fed’s quick rhetorical reaction to materialize.

Issuing clear statements about the Fed’s determination to intervene was one of the lessons that Ben Bernanke learned from Greenspan and applied during the toughest weeks of the great panic of 2008. He is portrayed by Wessel as being determined that he “would not go down in history as the chairman of the Federal Reserve who dithered and delayed during a financial panic that threatened American prosperity,” and he “adopted a new mantra: Whatever it takes.” The decision to intervene without compromise and fuel the global need for liquidity was quickly adopted by other central banks and international financial institutions such as the IMF. Sending the message to the global markets that the financial regulators were ready to do “whatever it takes” to avoid a global financial crisis, was probably the most important stabilizing element of the fear factor. It was a way to increase people’s subjective probability (see Ramsey) that words will be followed by

1. Ibid.
2. Woodward’s personal account.
4. Another catching phrase in Wessel’s book is ‘Before Asia Opens’, a mark of Bernanke and his decision to create full impact of his statements: “The balding, bearded chairman of the Federal Reserve managed a smile as he confided that he had a title for the book he would write someday about his watch as helmsman of the world economy: Before Asia Opens…”
5. The essence of pragmatism I take to be this, the meaning of a sentence is to be defined by reference to the actions to which asserting it would lead, or, more vaguely still, by its possible causes and effects.” (Philosophical Papers, p. 51.) http://www.fil.lu.se/sahlin/ramsey/
actions. Therefore, confidence had to be subsequently enforced by the concrete measures to back the initial efforts for moral suasion, observing Mervin King’s advice: “*Do as you say and say as you do*”\(^1\).

### 2. Conditions of Transparency

As suggested by the literature surveyed in the previous chapter, the discussion on central bank communication that follows will concentrate mainly on those aspects of communication that transcend the transmission of pure, concrete information. Although it is difficult to separate the informational content from meta-information (and indeed many cases discussed here inescapably take into account the role of information), it is important to distinguish between policy announcements that have an impact due to their very informational content (such as inflation statistics) and statements that transmit to the public the subjective interpretation of the monetary reality from the central bank’s perspective.

Obviously, in certain instances the information about the monetary policy stance contains an implicit interpretation of the economic reality, as in the case of an interest rate decision. Furthermore, the release of information about the bank’s decision to intervene for stabilizing the financial markets can send an important message creating confidence about the bank’s preparedness and decisiveness to act. The announcement of a ‘bailout plan’ as a response of the Obama administration to the financial turbulence, assured the public that solutions existed for safeguarding the financial system. In a similar manner, the one sentence statement\(^2\) of the Greenspan’s Fed in 1987 managed to calm the markets amid a stock exchange crash.

The role of central banker’s communication skills intervenes every time the bank’s private information is inconclusive or it refers to an uncertain set of elements in the future. In these situations, if the bank has a clear message to transmit but the informational content is not sufficient to create the desired impact, then the relational and contextual dimension prevails. The credibility of the bank, the framing of the message, the context

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2.“The Federal Reserve, consistent with its responsibilities as the nation’s central bank, affirmed today its readiness to serve as a source of liquidity to support the economic and financial system.”
of influence and the subjective perceptions of the public make the difference. If the monetary policy operations contain the central bank’s objective factors for influencing the economy, communication drives the subjective factors.

The main area of central bank communication is obviously monetary policy oriented toward containing inflation, the main mechanism being to use central bank’s credibility to anchor inflation expectations. When the economy is in long-run equilibrium, on the short term there is a negative correlation between inflation and unemployment (the Phillips curve). If prices and wages are rising, the central bank believes that inflation is unacceptably high, so it makes an announcement in this sense. In the short run, firms (wage setters) are locked into their previous agreements which already incorporate the inflationary expectations; hence a reduction in nominal money growth can lead to a reduction in the real money supply and unemployment. On the optimistic scenario workers believe that the central bank will stick to its tighter monetary policy and in the next round of wage bargaining, they can afford to ask for a much lower rate of increase in money wages without expecting any reduction in real wages, since they expected inflation to fall quickly. For the pessimistic scenario, workers do not believe that the central bank will persevere with its new tough monetary policy; therefore, they expect inflation to remain above the equilibrium inflation rate in the long run. Since they think inflation will remain high, workers cannot afford to take nominal wage cuts in anticipation of lower inflation. And if the central bank is increasing the money supply at a lower rate, in the short run prices are rising more quickly than the nominal money. The real money supply is falling yet again, aggregate demand is further reduced, and unemployment increases. Moreover, the worse this slump becomes, the more likely is that the government will conclude that unemployment has reached such unacceptable proportions that the money supply must be increased to boost aggregate demand again.

A plethora of studies find that credible central bank communications manage to anchor inflation expectations and thereof, to reduce inflation on the long run. This is actually the rationale for the enthusiastic
implementation of the inflation targeting framework in the practice of many central banks. While it would be beyond the size of this paper to review comprehensively the large body of literature on inflation targeting and the impact of communication on expectations stabilization, a few examples are useful as reference.

Michael Woodford was probably the most prominent and convinced supporter of the view that central banking is nothing else than management of expectations:

*The importance of communication strategy for policy effectiveness follows from a fundamental feature of the kind of problem that a central bank is called upon to solve. Central banking is not like steering an oil tanker, or even guiding a spacecraft, which follows a trajectory that depends on constantly changing factors, but that does not depend on the vehicle's own expectations about where it is heading. Because the key decision makers in an economy are forward-looking, central banks affect the economy as much through their influence on expectations as through any direct, mechanical effects of central bank trading in the market for overnight cash.*

Woodford (2005) analyzed comments about possible policy changes in post-meeting statements of the FOMC and correlated them with federal funds rate and the 10-year Treasury rate, showing that changes in wording anticipate changes in policy and affect market rates (Figure 1). In a similar approach to interpret the wording of central bank communications, Heinemann and Ulrich (2005) suggest, based on the case of ECB’s rhetoric (press conferences), that linguistic analysis can improve but not substitute more rigorous forecasting techniques. Nevertheless, they find that, with few exceptions, words matched the ECB’s monetary policy stance (Figure 2). Beyond the linguistic approach, there is a whole range of studies that find evidence that central bank communications and transparency manage to affect inflation expectations: Kuttner and Posen, (1999), Kohn and Sack, (2003), Orphanides and Williams, (2004), Reeves and Sawicky, (2005), Cruijisen and Demertzis (2005), Gürkaynak, Levin and Swanson, (2006),

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1. The debate about inflation targeting will be tackled in the following chapters as well.
Eusepi and Preston (2007), Svensson, (2009) etc., most of them proposing their findings as arguments or support targeting.

Figure 1: Impact of FOMC statements on interest rates (Woodford, 2005)

Figure 2: ECB’s discourse and policy stance
Apart from proper monetary policy communications for anchoring inflation expectations, a typical area for central bank oral interventions is the exchange rate policy. Moreover, even if actual and oral interventions in the exchange markets are complementing each other (Bernal and Gnabo, 2007), oral interventions might constitute, on a short term basis, an effective and autonomous policy tool\(^1\) (Fratzscher, 2004). Bernal and Gnabo (2007) describe the ‘topography’ of exchange rate interventions. If actual interventions imply central bank’s monetary transactions, oral interventions are pure announcements (speeches or communications by officials) not involving any currency transaction, and confirmed interventions are actual interventions accompanied by an announcement directly related to it (Figure 3).

**Figure 3: Topography of exchange interventions**

*(Bernal and Gnabo, 2007)*

The linguistic nuances used to convey messages about certain stances vis-à-vis the exchange rate developments are exemplified by Robert Rubin, former U.S. Treasury Secretary:

\(^1\) Fratzscher even argues that communication tends to replace actual interventions that are gradually abandoned.
I became very adept at simply repeating the mantra - except in those rare instances when we deliberately used a slight shading, always built around commitment to a strong dollar, to convey a message. For example, my saying "a strengthen weaken ambiguous strengthen weaken ambiguous strengthen weaken ambiguous strong dollar is in our national interest, and we have had a strong dollar for some time now" created great excitement at a press briefing, as it was construed to mean that we wouldn't mind seeing the dollar remain strong but soften somewhat. However, I would never give any explanation for such a change beyond my prepared phraseology.¹

If Fratzscher (2004) shows that official communications were efficient in influencing the exchange rate for the dollar and for the yen in the desired direction, Jansen and De Haan (2005) found that in the case of the Euro oral interventions had rather limited and short lived effects (Figure 4.–the solid line represents the fraction of successful verbal interventions, the dotted line represents the associated probability of exchange rate return). As far as the context of interventions is concerned, Fratzscher (2004), Barnett and Ozerturk (2005) find that announcements that ‘lean against the wind’ or deviate from the usual policy stance, tend to be substantially more effective. In terms of volatility of exchange rate markets, studies agree that communications reduce volatility (Beine et. al., 2004; Fratzscher, 2004; Jansen and De Haan, 2005), the absence of speeches having a negative on volatility (Beine et al., 2004).

Central bank communication is beneficial both for the bank and for the public and market participants. In the market for information, supply and demand begin to take shape, as central bank communication becomes a more permanent reality. When Keynes discusses the propensity to consume as a psychological law described by a functional relationship between \( Y_w \) income and \( C_w \) expenditure on consumption, \( C_w = \chi(Y_w) \), he outlines three categories of factors determining propensity to consume: a) the amount of income, b) other objective circumstances, and c) subjective needs and the

¹ Quoted in Fratzscher (2004).
psychological propensities and habits of the individuals\(^1\). For Keynes, both the propensity to consume and the propensity to save are actually psychological time-preferences, as the decision to consume or to save lies exclusively in the power of individual and therefore is contingent to human nature and preferences. When the central bank sets the interest rates or fights inflation, it acts on the present and the future value of money, therefore affecting people’s decisions towards consumption and saving:

**Figure 4. Success of verbal interventions (Jansen and De Haan, 2005)**

We leave saving to the private investor, and we encourage him to place his savings mainly in titles to money. We leave the responsibility for setting production in motion to the business man, who is mainly influenced by the profits which he expects to accrue to himself in terms of money. Those who are not in favor of drastic changes in the existing organization of society believe that these arrangements, being in accord with human nature, have great advantages. But they cannot work properly if the money, which they assume as a stable measuring-rod, is undependable. Unemployment, the precarious life of the worker, the disappointment of expectation,

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the sudden loss of savings, the excessive windfalls to individuals, the speculator, the profiteer—all proceed, in large measure, from the instability of the standard of value\textsuperscript{1}.

The subjective perceptions of this plethora of factors affecting spending, saving or investing is often affected through central bank communications. Expectations of higher interest rates in the future drive agents to reduce consumption and increase savings. Furthermore, Keynes (1925) suggests that the effect of higher interest rates works also in another direction than it is usually supposed. Unless the increase in interest rates is not offset by a corresponding change in the demand-schedule for investment, the latter will decrease, which in turn will reduce income thus consumption. The result could be that both consumption and saving will decrease. Keynes observes:

\textit{The more virtuous we are, the more determinedly thrifty, the more obstinately orthodox in our national and personal finance; the more our incomes will have to fall when interest rises relatively to the marginal efficiency of capital. For the result is inevitable.\textsuperscript{2}}

However, at this point, he misses an important ingredient of human behavior: confidence.\textsuperscript{3} Investors can decide to embark on new projects even if the actual economic outlook is not fully convincing, and in this type of situation the central bank has a voice and a role to play. Confidence in currency, in financial stability or in low inflation conditions can be conferred by the central bank, even if sometimes is hard to produce conclusive evidence to suggest the trends. A glimpse of the central bank’s way of thinking is usually enough to create monetary effects\textsuperscript{4} (Blinder, 2008).

The central bank’s interpretation of the economic outlook can create bubbles; can enhance the wealth effect thus affecting spending decisions. The

\begin{flushleft}
\textsuperscript{1} J.M. Keynes, Monetary Reform, 1925.
\textsuperscript{2} Ibid.
\textsuperscript{3} Although he mentions later in the same book that: “The physical conditions of supply in the capital-goods industries, the state of confidence concerning the prospective yield, the psychological attitude to liquidity and the quantity of money determine, between them, the rate of new investment.”
\textsuperscript{4} “Perhaps the best a central bank can do is to teach the markets its way of thinking.”
\end{flushleft}
framing and the modes of communication for financial information can create certain biases in public perceptions. Sotirovic (2001) analyzed public perceptions of welfare programs and the way these perceptions are explained by differences in individuals’ exposure to media. Her evidence shows that contextually poor, event-centered media represented particularly by exposure to entertainment programs works in the direction of discriminating welfare.\(^1\) On the contrary, watching more thematic television programs has positive effects on the accuracy of perceptions of welfare and consequently the support for welfare programs.

One conclusion is that both the factors influencing communication and those shaping perceptions are finally conducive to distortions, for the better or for the worse. If we talk about central bank communication as a phenomenon that is shaped both by the supply and the demand for information we can identify sets of factors that create certain predispositions for the sender and respectively the receiver of central bank information. I will call these predispositions the propensity to listen and the propensity to communicate central bank information.

The main factors for the propensity to listen:

\begin{itemize}
  \item [a)] Degree of financialization of the economy
  \item [b)] Level of public’s trust in the central bank
  \item [c)] General credibility of the institutional establishment
  \item [d)] Knowledge and interest that the average citizen has about the economy (knowledge gap, information asymmetries)
  \item [e)] Access to particular media (web content, financial news programs etc.)
  \item [f)] Development of alternative sources of financial information (CNBC)
  \item [g)] External factors that might create a sense of ineluctable dynamics in the economy
  \item [h)] Special circumstances (periods of financial turbulence etc.).
\end{itemize}

The main factors for the \textit{propensity to communicate}:

\(^1\) Welfare spending is perceived to be higher than it actually is, and recipients of welfare are perceived to be predominantly non-White, female and of younger age.
a) Normative environment prescribing rules of communication and disclosure (annual reports, press conferences, testimonies to the parliament etc.)

b) Central bank independence and legitimacy

c) Type of committee and decision making process in the bank

d) Character of the country’s tradition in dealing with the citizen

e) Personal abilities of bank executives to communicate

f) Role of the media (implication, cultivation)

g) Special circumstances (change of currency, e.g. adoption of euro etc.)

If we can talk about demand and supply of central bank information, then the supply and demand framework suggest that an equilibrium level of central bank communication is at the point where supply and demand meet. Factors affecting the two schedules will inevitably affect the equilibrium, on short and long term. On the long term, the supply of central bank information can create its demand, i.e. if the public becomes more educated and if attentiveness is stimulated. It is even relevant to speak about the elasticity of demand for central bank information, to the extent to which, for example, high dependency on the central bank’s private information excludes alternative informational source and creates rigidities in public perceptions. The result is the crowding out of private information (Morris and Shin, 2002) or the ‘paradox of credibility’ in the sense that the inelastic demand for information transforms the central bank into an informational monopoly that finally fails to meet the public’s expectations.

3. Transparency Versus Secrecy

As seen from the literature, transparency is useful for credibility, accountability and ultimately for policy effectiveness. A transparent policy regime is one in which the public knows what the central bank should do. Whatever arrangements concerning democratic accountability may exist, their scope is limited without transparency because information concerning the institutional behavior is crucial for the evaluation of its performance. When monetary decisions are transparent, it is easier to make a judgment and to hold the central bank officials accountable for their behavior.
A central bank should be required to report at regular intervals on its past performance as well as on future plans for monetary policy in accordance with the monetary objective. As Bini-Smaghi and Gros (2000) explain,

*Transparency increases the credibility of the central bank, especially when the latter does not enjoy a particularly high reputation. It thus enables the central bank to conduct a less restrictive monetary policy than would otherwise be required. Transparency and accountability increase the overall welfare of the economy.*

As the monetary policy acts directly only on short term interest rates, the transmission mechanism towards the long end of the interest rate spectrum depends essentially on market expectations about future central bank decisions. The role of expectations is clearly explained by Blinder (1998):

*Central banks generally control only the overnight interest rate, an interest rate that is relevant to virtually no economically interesting transactions. Monetary policy has important macroeconomic effects only to the extent that it moves financial market prices that really matter—like long-term interest rates, stock market values and exchange rates. The links from the direct lever of monetary policy (the overnight rate) to the prices that matter depend almost entirely upon market expectations.*

**Figure 5: Factors of transparency (Cruijsen and Eijffinger (2007))**
Woodford (2005) goes even further, stating that expectations are in fact the most important transmission mechanism for monetary policy: “not only do expectations about policy matter, but (...) very little else matters.” Cruijsen and Eijffinger (2007) explain that actual and perceived transparency differ due to a number of factors related to knowledge, beliefs, perceptions etc. (Figure 5).

A comprehensive and elaborated index of central bank transparency has been constructed by Gerrats and Eijffinger (2003), (2006). The results of their research not only illustrate the underlying determinants of central bank transparency but also indicate a significant correlation between transparency and monetary policy performance, i.e. lower nominal interest rates. In their analysis, transparency is proved to enhance the credibility, reputation, and flexibility of monetary policy, thus leading in the long run to the result of lower nominal interest rates.

More recently, Crowe and Meade (2008) measured with a new methodology the levels of central bank independence and transparency in large set of countries. They found that independence and transparency are significantly correlated, while transparency is also determined by the quality of the national institutions. Furthermore they identified an interesting determinant of transparency in the feedback the central bank receives from its communication to the private sector (Table 1).

A conceptual framework better illuminates the intricacies of transparency and communication in the case of a central bank. Winkler (2000) has constructed a pyramid of a transparent monetary policy strategy in which he stresses the importance of simplified and condensed information in the communication strategy of a central bank to the different external target audiences. He relates greater transparency expressed by central banks with greater clarity (Figure 6).
Table 1: Comparative transparency index (Crowe and Meade, 2008)

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<td>USA</td>
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Figure 6. The Transparency triangle of monetary policy (Winkler, 2000)
Honesty is defined as the degree to which the representation of information employed in external communication corresponds to the actual structuring of information adopted internally. The external communication reflects to a certain extent the internal framework in structuring and interpreting the information. Concluding, it is not only the degree of openness but also the informational efficiency, relevance and clarity for the audience, which should be taken into account to assess the degree of transparency of the ECB. Beyond the provision of information, it is more the provision of knowledge about the economic outlook and the monetary policy objectives that the central bank has to convey to the public. In a sense, Issing (2000) considers central bank communication a more complicated matter that simple public relations-by underlying the importance of a whole setting of accountability and transparency-but in another sense he regards communication as a method to simply create the subjective feeling of familiarity.

But being open and being predictable are two different things. If the ECB’s monetary policy is not intelligible this is partially due to the fact that transparency is not about the crude provision of information. Rather, transparency is better defined as the provision of understanding (Harrison, 2001) or explanation of the bank’s way of thinking (Blinder et al. 2008). But the technicalities of communication and the philosophy of the communicator make the difference between intelligible and confusing messages. In a similar perspective, Mervyn King, deputy governor of the Bank of England, has argued that “successful monetary policy should be boring”. He contends that changes in interest rates should be predictable, not to make headline news. “Successful central bankers should be seen as neither heroes nor villains, but simply as competent referees, allowing the game to flow”. This approach suggests a certain interpretation of the differences between the leadership style of the ECB and the one of the Federal Reserve.

Can we speak about central bank transparency as a categorical imperative? While communication and transparency are closely related in

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many ways, they are not identical: although communication can be a means to achieve transparency, not all communication necessarily contributes to transparency. As we will see, it is not only that communication is a risky business for a central banker but even transparency has its drawbacks. Experience shows that the way policies are perceived by the public can be at times beneficial but also detrimental for the performance of the policy maker. There is probably a way to transmit information to the public in such a form that it creates the optimal context for the realization of policy goals, but this can only remain an ideal for policy makers. As Issing (2005) observed, in an ideal world, “the optimum amount of information is determined by the point where the supply and demand curves intersect”.¹

Cruijsen, Eijffinger and Hoogduin (2008) show that transparency has its pitfalls. They suggest that there is an optimal level of central bank transparency beyond which communication risks become redundant and spoil the perceptions of the public vis-à-vis the implementation of the monetary policy. The risks are that people might: (1) start to attach too much weight to the conditionality of their forecasts, and/or (2) get confused by the large and increasing amount of information they receive. Gerrats, Eijffinger and Cruijsen (2006), in their analysis of transparency scores for major central banks, also point out the fact that in some cases increased transparency is negatively correlated with interest rates. This fact seemed to have been even speculated by the Fed in 1994, with the unusual announcement of an interest rate decision.

Mishkin (2004) finds that transparency could go too far when excessive focus on central bank communication could weaken support for monetary policy long term objectives. This time-inconsistency problem is further amplified by interference of central bank communication and objectives with the political process that often directs perceptions on a completely different time horizon of policy making. Gerrats, Eijffinger and Cruijsen (2006) identify even a time-inconsistency problem inherent in the central bank’s transparency as it is influenced by economic circumstances. Evidence

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suggests that central banks tend to become more transparent when interest rates are low compared to the macroeconomic situation and to become more opaque when things go the wrong way. Furthermore, central banks are not far from window dressing or from spin-doctoring public perceptions, a fact that poses moral problems but can also be traced back to an honest approach to effective central bank communication that has to use simple words (Woodford, 2005) to portray complex situations, thus giving the impression that the world is more straightforward and secure than it actually is (Issing, 2005).

Morris and Shin (2000), continued by Amato and Shin (2003), suggest that too much information can harm the capacity of market participants to take actions appropriate to underlying fundamentals. If it is desirable for monetary policy to be accompanied by timely publications, statistics and media addresses, excessive disclosure of central bank information to the public could result in crowding out of private information from other sources. One conclusion is that in the absence of private information, the dissemination of public information increases welfare, but when agents have access to independent sources of information, the welfare effect of increased public disclosure is ambiguous. It is illustrative for this argument that the first version of the Morris and Shin paper was circulated under the title “The CNBC Effect” suggesting the pernicious effects of markets moved by a single dominant source of information. At the end of the day, as J.M. Keynes observed there is always a risk of herd behavior in the financial markets that could lead to a tendency of blindly following the average opinion or in the worst case to bank panics and runs. Here is how he describes the underlying mechanism, talking about the way people form their investment preference:

Professional investment may be likened to those newspaper competitions in which the competitors have to pick out the six prettiest faces from a hundred photographs, the prize being awarded to the competitor whose choice most nearly corresponds to the average preferences of the competitors as a whole (…) It is not a case of choosing those which, to the best of one’s judgment, are really the prettiest, nor even those which average opinion genuinely thinks the
We have reached the third degree where we devote our intelligences to anticipating what average opinion expects the average opinion to be. \(^1\)

4. Conclusions

If we maintain that communication takes place when one mind acting upon its environment influences another mind, and if we consider that other mind to be the central bank’s audience, we realize the limitations of our understanding of central bank communication and transparency. The last decade of extensive research on the subject, produced significant theoretical and empirical results about how central banks talk, completing previous theories on strategic information transmission, cheap talk, framing etc. Nevertheless, a lot remains to be done about closing the communication gap between central banks and their audiences.

After more than a century of utmost secrecy and cryptic discourse, the last two decades of increasing openness and transparency had encouraged both central bankers and scholars to look for more achievements in this direction. The financial markets know much more today about the thinking and decision-making behind monetary policy actions. Central banks talk much more systematically and intelligibly with their audiences, in the hope to anchor inflation expectations, to stimulate growth and to guide market participants through the muddle of financial turbulences.

However, the general public remains to a large extent ignorant and distracted from central bank communications. The low level of economic literacy within the general population, the evolution of media programs toward entertainment and the decreasing level of interest in public affairs, are some of the obstacles in the communication process between central banks and the public. In order to cope with these obstacles, central banks seek on one hand to improve their use of media and communication techniques, and on the other hand to attract and educate the public to listen and understand monetary policy. The result should be that the supply and demand of central

\(^1\) J. M. Keynes, The General Theory…., 1936.
bank communication would meet at a point that is beneficial for both parties involved.

Transparency is important but it is only a mere background of the semiotic architecture of a central bank. Beyond mere transparency, effective central banking needs predictability and credibility. More talk doesn’t necessarily mean more transparency, and better rhetoric doesn’t always mean higher persuasion. For central banks to become more persuasive, they need to focus also on the ‘demand side’ of communications. A persuasive central bank manages not only to anchor inflationary expectations but also to affect output in the desired sense, as the public alters consumption and saving decisions.
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Legal Aspects of Unauthorized Bank Payments

Mostafa Elsan*

Abstract

One of the complex matters in banking law is the problems and mistakes which occur in the process of bank payments. Mistake of banker or error in processing of information in bank networks may result in payment delay or paying money to the account of a person other than who was really intended. This article is about rules for allocation of losses between account holders implicated and the intermediary bank-based payments.

The paper discusses common mistakes and usual forms of unauthorized payments with intermediation of one or more banks. The main idea of this paper is that the bank may be responsible for some errors and mistakes; even if there is no agreement about or against this liability.

Keywords: unauthorized payment, liability of bank, payment by mistake, misuses notice, customer’s obligation.

JEL Classification: K20, K22, K35

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Introduction

The contract between the customer and the bank is classified as a debtor-creditor relationship in all types of bank accounts. This contract requires the bank to honor all valid and proper orders of the customer to pay amounts from his account with the bank, as long as funds remain available in the customer's account.

In a bank payment, one or more than one bank is involved as agent of their customers. It is not likely that particular payment be contrary to the mandate of payer or made according to an unauthorized forged signature or in spite of customer’s order (notice) to the bank to stop payment or to block his account or refrain from payment of particular instrument or to paying to certain person. As another problem, which may arise in the relation of a bank and its customers, the instruction of payment may be issued by dishonest or unauthorized person. It is not impossible that a given payment be erroneously effected twice or the payer becomes insolvent before receiving payment.

Generally, restitution of money paid by mistake or law, needs to be claimed in a competent court. However it is possible that the bank conclude contract or insert a term in contract of deposit to reimburse the money paid by mistake from the account of the customer who was unjustly enriched from such payment. Anyway, the burden of proof and expense of mistake or unauthorized payment is imposed to a person who is wrong at the time of payment. That person could be the payer or payee's bank.

This paper is divided into two parts as follows: Rules governing unauthorized bank payments (part I), and classification of unauthorized bank payments (part II).

Part One: Rules Governing Unauthorized Bank Payments

Reliability of legal relations as a principle requires accepting some measures including legitimacy of holder’s possession as a proof for his ownership. As another rule, the customer has both legal and contractual duty to inform bank about any problem such as crimes against his bank account or negotiable instrument or even missing of his payment bills or orders. These matters will be discussed as follows:
I. Protection of Legitimate Holder

Section 3-302 of United States’ Uniform Commercial Code (UCC) provides a measure for recognition of true holder. It states that the holder of a negotiable instrument who (1) gave value (2) in a good faith and (3) without notice of a claim or defense to the instrument or notice that the instrument is overdue, is a holder in due course. Section 3-305 of UCC then provides that a holder in due course cuts off all claims of third parties to the instrument and all defenses (except particularly serious defenses which are listed in section 3-305 (2) and are known as real defenses).¹

Therefore, as a rule, a holder in due course of a cheque will normally have an undisputed claim to payment by the bank. This protection should be given to persons who are not holders in due course, but who have in good faith changed their position in reliance on their ownership of an instrument or it proceeds in disputed.²

The above rule seems to be applicable, but partly, in Iranian law, due to the fact that the structure of “misappropriation” doctrine (ghasb) is applicable as a general rule in all parts of property law including negotiable instruments. As an acceptable rule in commercial law, holders who have good faith should be protected against malicious endorsers or fraudulent issuers of bills of exchange or cheque. Article 325 of Iran civil code provides a full protection umbrella in favor of holder of others’ property in good faith not against the true owner or beneficiary but against a transferor (e.g. seller) who has knowingly and so deliberately sold property which belonged to another.

About bank cheques, holders of those cheques enjoy two advantages not given to ordinary cheques. The first one is that they are assured of solvent obligor because the bank is certifying that received the fund from applicant of this cheque and then issued it. The second one is that the holder of a bank cheque is generally assured that payment cannot be stopped without reason and thereby, collection of this cheque is made more convenient.

2. Ibid, 142.
Consequently, a claim that the payment has been unauthorized is conflicting with the accepted rules of private and banking law and should be proved by claimant. Until providing such proof, the ultimate payee of fund is recognized as holder in due course of instrument at the time before its collection and then he is also regarded as legitimate payee (lawful receiver of money) after its payment.

II. The Customer’s Duty to Inform Bank about any Problem

As a rule of banking law, any customer owes a duty to inform his bank about any crime, missing, mistake or error in any kind of payment order as soon as he becomes aware of it. This is regarded as a duty of customer to inform his bank and thus by accepting this duty deliberate silence may become significant and amount to a representation.1 For establishing this duty it is immaterial that who acquired the payment order and whether the bank is able to know the problem and declined from payment or not.

The measure of duty to inform is the act of reasonable person. Therefore, if a customer fails to report a crime on payment order to the bank, before its payment, he is not liable for losses of bank. In Common Law such circumstances do not raise an estoppel against customer.

Part Two: Classification of Unauthorized Bank Payments

As a first matter, a bank payment may be requested or completed under a crime. So it needs to stop this type of payment or recognize the right of reclamation for true owner of money misappropriated. Second problem is that sometimes the payment of bank is contrary to the mandate of the customer (payer) and this may oblige the bank to recover the payer. Thirdly, a bank payment may be made by mistake of cashier or error of banking networks and finally payment may be done after misuse notice of payer or true owner to the bank. In this part we will discuss these 4 subjects respectively.

I. Payment under a Crime

Where an instrument obtained by a crime such as theft or fraud or a signature on a bill is forged or placed thereon without authority of the person whose

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signature purports to such instrument is wholly invalid and no right to holder for retaining the instrument or using it to discharge his obligations or enforce payment against issuer.

According to Article 14 of Iranian Cheque Issuance Act, “the issuer of a cheque or any beneficiary or legal representative can give to the bank a written declaration that the cheque has been acquired by finding it or theft or forgery or other crimes like as fraud or disloyalty. In these circumstances the bank should stop payment after revealing the identity of holder. For preserving rights of holder, the bank will issue a certification of non-payment indicating the cause of it. The holder can sue against the applicant of stop order and it could be a crime against the issuer of cheque if it is proved that his application of stop order was wrong”.

If the paying bank disregards that declaration to stop order and collect the cheque, it will be responsible on behalf of the true owner of that cheque or his legal representative.

In relation to the money paid by such instrument, the legal rules of unjust enrichment will apply. So the true owner of the cheque can sue against the bank which was in fault and the unduly recipient of fund by showing himself as rightful owner.

II. Payment Contrary to the Mandate

Generally in current and other forms of account, there is an agreement between bank and the owner of account which authorize the bank to pay an instrument according to an order if given instructions are in accordance with the terms of that agreement.1 For example, if in the agreement it was required that the order should be signed by A and B, the signature of one of them could not be sufficient. Thus, if the bank honors a cheque bearing a sole signature it has breached the mandate and could be responsible in behalf of the customer (account owner) or true owner of that cheque.

According to the yardstick of Article 3 of Iran Cheque Issuance Act, if the face of cheque wholly or partly be contrary to the pre-mandate of cheque

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issuer (depositor) to the payer bank, the latter should stop the payment. For preserving the rights of holder, Article 4 of that Act states that the bank must issue non-payment declaration (certification), by determining the cause or causes of it, and give it to the holder of the cheque. The holder could use it as evidence against the issuer of the cheque, if he proves that the stop order has been unduly wanted.

An important question is about discharge of obligation of payer by an unauthorized payment. Does a bank that has been paid a legitimate debt of its customer, but contrary to his mandate affirmed in their agreement, can recover the paid money from that customer? Positive answer to this question seems to be reliable. In Common Law according to equitable approaches to some cases,¹ a person who has been paid the debt of another one without authority is allowed taking advantage of his payment. So if the final result of unauthorized payment is discharge of obligation of payer the banker will be entitled to the benefit of that payment, provided the bank can prove that such payment went to discharge a legal liability of the customer. In this case in fact there is no loss to customer because the legal obligation which has to be discharged is discharged.²

In Iran law, it seems that the above approach is acceptable. According to Article 267 of Iran Civil Code, anyone can pay the debt of any debtor, with or without his permission. The only effect of permission is that it provides the right to demand the payment obligation for payer. As a rule in Islamic law, without prior permission to pay, there is no right to demand. This rule could be problematic for banks when they are paying debts of their customers but with some incompatibilities in the formalities of payment instruments. For resolving the problem, a bank can provide a term for acquiring customers pre-consent for such payments in its deposit contract. Of course if there was no debt, the payment which has been done by bank is based on incomplete or faulty instrument and thus incur all of losses of fund to the bank itself and the bank has no right for debiting account of the customer. In this case, the result

¹. A L Underwood Ltd v Bank of Liverpool & Martins [1924] 1 KB 775 244; Liggett (Liverpool) Ltd v Barclays Bank Ltd [1928].
². Wright J at A L Underwood Ltd v Bank of Liverpool & Martins [1924].
of unjust enrichment is conceivable only between the bank and payee and the customer of the payer bank has not any obligation or duty in this relation.

III. Payment by Mistake or Error

Sometimes unauthorized payment is driven from banker’s mistake of fact or law or from any type of error in computers or network of bank. So, there are typical differences between the processes of occurrence of mistake in comparison with error. However, in general, the consequences of both of them are the same for payer, his bank and payee and his bank. If payment has been made because of an error, recovery may be claimed either from the ultimate payee or from his bank. In many cases the two may be sued jointly.\(^1\)

Legal effects of mistake is imposed on the bank as organization when its officer or network did a mistake or error. This is because the contract on which the payment is based e.g. deposit or current account contract, has been concluded between bank and its customer. Therefore, the customer has a contractual right to demand money paid mistakenly or by error from his account. Of course his bank right to sue against mistaken officer or deceive party (ultimate payee) may be protectable by criminal law or tort.

It is important to be noted that criminal sanction for unintentional or erroneous conduct is rarely available. Because there are no mens rea (mental element of a crime), as one of essential elements of criminal conduct, exist in wrongful or erroneous act. Especially recognizing criminal liability for payee (ultimate receiver of paid money) is not possible in Iran criminal law even if he has been removed those funds from his account knowing that those monies are not belonging to him. This act could not be regarded as “theft” because it has not had one of the essential elements of theft i.e. “robbing”. Banker’s mistake or bank’s network error is not crime of breach of confidence; due to the fact that it has not the element of intentionally “deposit” to the receiver of money. Therefore, there is an apparent gap in Iran criminal law about withdrawal of unjust money which credited without

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causation to the account of one person because the title of no crime is fitting to this conduct.

In tort, the act of the receiver of unjust money is totally coinciding with the concept of unjust enrichment. As a rule in all of civilized systems of law, the law bounds to provide remedies to prevent a person from retaining the money or some benefit derived from another which is against conscience that he should keep. Such remedies fall within a category of quasi contract or restitution. Payment under mistake of fact is only one head of this category of the law. The gist of the action is a debt or obligation implied or more accurately imposed by law.¹

For proving unjust enrichment the plaintiff (payer or his bank) must claim for “restitution”. For a restitutionary claim to lay payer or his bank must show that: (i) the defendant (payee) has been enriched at the claimant expense and (ii) the circumstances are such that the enrichment must be given up to claimant. In other words, the enrichment was “unjust”.²

Finally, it should be noted that the effects of customer’s personal mistake or misunderstanding is imposed to himself only, not to his bank. This is because payment by bank is based on a contract between bank and customer and the bank only is agent of him. “The general rule in contract is that a contracting party is not relieved from his obligations merely because he misunderstood the effect on the agreement of miss-assessed extrinsic factors”.³

IV. Payment after Misuse Notice

In some situations the bank is receiving a notice that an agent acting on behalf of a customer is misusing his authority in order to misappropriate his principal money. In such cases two duties of a bank are conflicting each other. From one hand, the bank has duty of care about deposits and funds of its customers and in the other hand, it has duty to honor payment instructions given in accordance with customer’s mandate.⁴

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For resolving this conflict looking deeply to the concept and extent of both duties of bank (care and honor) are necessary. About “the duty of care”, as Steyn J. stated “in the absence of telling indications to the contrary, a banker will usually approach a suggestion that a director of a corporate customer is trying to defraud the company with an initial reaction of instinctive disbelief”.

Therefore, trust is the basis of a bank’s dealings with its customers.

Concerning the bank duty to honor payment instructions, it is important to note that the banker should rely only on apparent factors in a payment order or instrument such as the standing of the corporate customer, the bank’s knowledge of the signatory, the amount involved the need for a prompt transfer and the presence of unusual features. The scope and means of making reasonable inquiries may be relevant and could be observable. Thus, the banker has not any duty to inquire for example about the facts of relation between a company and its chairman and managers. What is important to the bank is passing banking formalities by payment order. So, if in the network system of bank, there has been only one signature of chairman of a company declaring as essential and it was consistent with by-law of that company, the bank has no duty to investigate for example about decision of shareholders on need to the signature of auditor of that company.

Accordingly, as May LJ stated about cheques, it is considered as reasonable duty to bankers to pay his customer’s cheques in accordance with his mandate. So, there are very rare situations in which cheques should not be paid immediately upon presentation and need reasonable enquiry. Those circumstances are so that any reasonable cashier would hesitate to pay a cheque at once and refer it to his or her superior.

In these cases, when a reasonable superior waver to authorize payment of such cheques it could be said that they are not payable and the bank should prefer the duty of care to the duty of honor payment instructions apparently given in accordance with the customer’s mandate only in such circumstances as a narrow exception to the latter duty. That is because the banker’s duty of honor is derived directly from his contractual obligation mentioned in current

or other types of bank accounts. Thus the order of the same customer for stop payment should not be admissible for bank unless it is accompanied with evidences or proofs indicating its reasonability and acceptability according to the law. The structure and mode of statement of Article 14 of Iran Cheque Issuance Act is confirming this argument, too.

**Conclusion**

As a rule in banking law, if a bank pays a cheque after a timely stop payment order by the depositor (issuer of the cheque), the bank is usually liable to the depositor for the amount paid. This rule applies in other types of payment orders. As another rule, if the payment order or instrument has been already paid, cleared or certified by bank, thus the depositor or claimant of its ownership cannot place a stop payment on an instrument like this. However his claim of unjust enrichment is actionable in competent court provided to all its conditions and limit.

Finally, the “cash” is a single way to discharge obligations. Therefore, negotiable instruments and all other payment orders are conditional payment orders. Thus, as a general rule, unless otherwise instructed, a bank, as an agent for collection of obligation in behalf of its customer, has no authority to receive in payment anything but cash, and when the bank does accept anything other than cash in payment it will be liable to his principal for any loss the latter may suffer. Therefore the liability and burden of proof of discharge is not on obligator (payer) but on bank or payee. If there was any problem in collection of a payment instrument, between the bank and payee, “whenever one of two innocent persons must suffer by the acts of a third, he who has enabled such third person to occasion the loss must sustain it”.  

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References


Bankruptcy Prediction: Dynamic Geometric Genetic Programming (DGGP) Approach

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Abstract

In this paper, a new Dynamic Geometric Genetic Programming (DGGP) technique is applied to empirical analysis of financial ratios and bankruptcy prediction. Financial ratios are indeed desirable for prediction of corporate bankruptcy and identification of firms’ impending failure for investors, creditors, borrowing firms, and governments. By the time, several methods have been attempted in the use of financial ratios on predicting bankruptcy but some of them suffer from underlying shortcomings. Recently, Genetic Programming (GP) has received great attention in academic and empirical fields of solving high complex problems. The paper proposes the use of Dynamic Risk Space measure (DRS) on bankruptcy prediction utilized with Genetic Programming technique. The paper provides the evidence of the extent to which changes in values of this index are associated with changes in each values axis and how this may alter our economic interpretation of changes in the patterns and direction of risk. Results of Dynamic Geometric Genetic Programming (DGGP) classification methodology is compared with

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common and transformed ratios. Results confirm the better accuracy which Genetic classification tree achieved (overall 95.14% accuracy rate) using transformed ratios approach while original ratios model achieved only 88.85% accuracy rate.

**Keywords:** Genetic Programming, Dynamic risk space, Financial ratio, Risk box, Bankruptcy,

**JEL Classification:** C01, C02, C13, C61
1. Introduction

In recent decades business failure prediction has been one of the major research domains in financial researches to evaluate the financial health of companies (Grice and Dugan, 2001). While bankruptcy involves a large social and economic costs, corporate failure prediction has been stimulated both by private and government sectors all over the world (Charitu et. al., 2004). Moreover, company failure may inflict negative shocks for each of the shareholders, thus the total cost of failure will be large regarding to economic and social costs (Shumway, 2001).

Beaver (1967) showed that corporate failure could be reliably predicted through the combined use of sophisticated quantitative using selected financial ratios. Altman (1968) extended this narrow interpretation by investigating a set of financial ratios as well as economic ratios as possible determinants of corporate failures using multiple discriminant analysis specifically the Z-score model. Financial ratios are widely used for modelling purposes both by practitioners and researchers. Practitioners use financial ratios to forecast the future success of companies, while the researchers' main interest has been to develop models exploiting these ratios.

Since Altman (1968), the literature on predicting bankruptcy has witnessed numerous extensions and modifications and various techniques have been developed to measure risk and predict bankruptcy. However, none of them had a perfect predictor functional form and all procedures utilized common ratios without any theoretical basis (Bahiraie, 2011). Previous researchers all tested their models empirically using data sets and the main results shows that financial ratios have significant effect on bankruptcy risk, return, credit risk, commercial risk, market and economic conditions. Recently, several attempts have been made to solve problems of using accounting-based financial ratios in statistical analysis, but none has been entirely successful on quantitative and objective systems for bankruptcy prediction (Andres et. al., 2005). Such attempts have included trimming the sample ratios, eliminating negative observations, and use of various

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1. For more details about financial ratios properties, see Watson (1990) and Tippett (1990).
transformations such as logarithms and square roots to achieve more normal distributions (Canbas et. al., 2004). Most of these attempts have utilized the use of common ratios which may exceed cost of errors in analysis and misspecification. As yet, no convenient and superior alternative modified ratio has been developed and applied\(^1\).

Technically, financial ratio is of the form X/Y, where X and Y are figures derived from the financial statements or other sources of financial information. One way of categorizing the ratios is on the basis where X and Y originate (Foster, 1986). In traditional financial ratio analysis both X and the Y are based on financial statements. If both or one of them comes from the income statement the ratio can be called dynamic while if both come from the balance sheet it can be called static. The concept of financial ratios can be extended by using financial statement information as X and Y in the X/Y ratio.

In this paper we construct a new methodological approach to financial ratio analysis called the Dynamic Risk Space measure (DRS) which involves data transformation and we illustrate the use of this method for measuring financial risk in prediction of bankruptcy risks. For illustration of this new methodology, we used X as numerator and Y as denominator of common ratio values and represented as Cartesian coordinates in our constructed modification box in which we derive the isoclines of associated components of bankruptcy risk.

For testing procedure, the results of genetic classification trees and accuracy levels will be compared for each transformed and original ratios procedures. In this study, we investigate possible application of GP\(^2\) for bankruptcy prediction modelling considering use of different forms of variables as common ratio variables and our new geometric approach.

The remainder of paper proceeds as follows. In section 2 we will summarize existing methodologies and their general framework following recently proposed static geometric approach called Risk Box. Subsequently

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1. Some exposition on some of the weaknesses in the use of common ratios such as scaling, proportionality and symmetric effects are provided in Bahiraie et al. (2008) and, Azhar and Elliott (2006).
2. Generic programming
we briefly derive our new methodology named Dynamic Risk Space (DRS) and its components analytically. Section 3, describes Genetic Programming classification method. Section 4 illustrates an empirical application using Genetic Programming (GP) and we summarise and conclude in Section 5.

2. Literature Review

2.1. Transformations

According to literatures, variables were used in previous studies generally exhibit non-normal distribution (Barnes, 1982; Ooghe and Verbaere, 1985; McLeay and Omar, 2000) and researchers made correction for univariate non-normality and tried to approximate univariate normality by transforming the variables prior to estimation of their model. Deakin (1976) used logarithmic transformation for the lack of normality for distributions, and then Foster (1986) used square root and lognormal transformation of financial ratios. However, logarithmic transformations and square roots are even more difficult to interpret because they can alter the natural monotonic relationships among data (Canbas et al., 2004).

Other researchers approximate univariate normality through 'trimming' by the method known as 'outlier deletion', which involves segregating outliers by reference to normal distribution (Ezzamel et al., 1990). Such deletions threaten external validity and interpretation of results. Moreover, when data are arbitrarily truncated, important information concerning the research question may be discarded, thus greatly constraining the research task (Sun et al., 2007). Furthermore the rank transformation used by Perry et al., (1986) and Kane et al., (1996) reported an improvement in fit and is less biased than linear models with untransformed data. Recently Ooghe, et al., (2005) used Logit transformation to achieve better accuracy.

Conversely, in fact there are no general guidelines concerning the appropriate approach to financial ratios. Furthermore none of the previous attempts had perfect prediction in functional form, and all of the procedures utilized the use of common ratios without considering numerator and denominator, which are the most essential factor concerning each ratio value.
2.2. The Risk Box (Share Risk Method)

The framework proposed by Bahiraie et al. (2008) is a two-dimensional box with pair values of risk ratios. To define the risk ratio, we let the numerator as X and denominator as Y which is represented as Cartesian coordinates. For exposition purposes suppose our proxy for risk chosen is employed numerator(X) and denominator(Y) values. Consider $\forall t = 1, 2, 3, ..., n$. For each values we have $X_t, Y_t, TR_t, NR_t, OR_t, SR_t > 0$ which are all risk components measuring indices such as, Total Risk $TR = X + Y$, Net Risk $NR = |X - Y|$, Overlapping Risk $OR = (X + Y) - |X - Y|$, and lastly the proposed Share Risk measure (SR) as defined below, are linear functions of $X$ and $Y$ equals a constant which is total risk for specific ratio. Numerator(X) + Denominator(Y) = Total Risk = Net Risk + Overlap Risk

\[ X + Y = TR = NR + OR \]  \hspace{1cm} (1)

Then:

\[ SR = \frac{OR}{TR} = \frac{(X + Y) - |X - Y|}{(X + Y)} = \frac{2 \min(X, Y)}{(X + Y)} \]  \hspace{1cm} (2)

We can construct the two dimensional box to encapsulate all of these variables for $n$ years. The dimensions of the risk box are generated by the maximum value of either X value or Y value during the period of study. From the definition of TR, NR, OR, SR, we obtain:

\[ \max(NR_t) = \max(|X_t - Y_t|) \leq \max(\max X_t - \min Y_t, \max Y_t - \min X_t) \leq m \]  \hspace{1cm} (4)

\[ \max(OR_t) = 2 \max \left( (\min(X_t, Y_t) \right) \leq 2m \Rightarrow \max SR_t \leq 1 \]  \hspace{1cm} (5)

Each respective risk box will have sides equal to $\max(X_t)$ if for $i \in t$ $\max(X_t) > \max(Y_t)$ or $\max(Y_t)$ otherwise. Our exposition of the dimensions of the risk box is described below that confirms the elasticity and unit-free nature of SR measure.
In Figure 1, to determine relationships between the four risks measures and slopes $\gamma$ and $\gamma^{-1}$, consider rays OB and OC substance the angles $\theta_1, \theta_2$ measured from the symmetry axis. Let A, B, C, and D represent points on the risk plane with A, B and C sharing equal total risk values, TR*. In addition, B, C, and D share equal OR values, OR*.

\[ OA = TR^*, \quad \text{and} \quad TR^* - OR^* = NR^* = AB \]  

(7)

Hence

\[ \tan \theta_1 = \frac{AB}{OA} = \frac{TR^* - OR^*}{TR^*} = 1 - \frac{OR^*}{TR^*} = 1 - SR^* \quad \Rightarrow \quad SR^* = 1 - \tan \theta_1 \]  

(8)

These relationships will confirm that SR values are constant along any ray from origin and the two extreme cases. These two extreme cases are (i) $\theta_1 = \theta_2 = 45^\circ$, in which case SR=0 and either the numerator value X or the denominator value Y is zero, and (ii) $\theta_1 = \theta_2 = 0^\circ$, in which case SR=1 and X=Y.

Recall the Overlapping Risk, $[OR = 2\min(X, Y)]$, below the central 45° line, $OR = 2X$ which remains constant for constant X and above the line,
$OR = 2Y$ remains constant for $Y$. Thus the equation corresponding to constant overlapping risk $OR^*$ is L-shaped (see Figure 1), the kink occurring along the central 45° line. As $OR^*$ increases, the kink moves up the line, away from the origin.

In the next section, we will construct an improved version of the risk box known as Dynamic Risk Space which is able to handle not only negative values but also any changes regarding the ratios.

3. Methodology

3.1. Genetic Programming (GP)

As to date, there are many classical cross-sectional statistical methods in corporate failure prediction like univariate analysis, risk index models, multivariate discriminant analysis (MDA) and conditional probability models such as Logit, Probit and linear probability models. MDA is not free from defects because it depends largely on some restrictive assumptions such as linearity, normality, independency among input variables and pre-existing functional form relating the independent variable and independent variable. To overcome the disadvantages of MDA and provide higher prediction accuracy, later studies used Logit (Ohlson, 1980) or Probit (Zmijewski, 1984) to construct their predictive modes. Also, some sophisticated alternative methods produce better performing failure prediction such as fuzzy rule-based classification model, Multi-Logit model, dynamic event history analysis, multidimensional scaling, rough set analysis, expert systems specifically neural networks, genetic algorithms and genetic programming (Landajo et al., 2000).

Although there are other alternative methods which are computationally more complex and sophisticated than classical statistical methods, it is not clear whether they produce better performing corporate failure prediction models and whether the use of statistical techniques is valid under very restrictive assumptions (Ooghe and Spaenjers, 2006). Moreover, all these methods are diverse in problems, such as dichotomous dependent variables,
sampling method, non-stationarity, data instability, annual accounting information, selection of independent variables and time dimensions.

Genetic programming (GP) is a search methodology belonging to the family of evolutionary computation (EC). GP can be considered as an extension of Genetic algorithms, GA (Koza, 1992). GA is stochastic search technique that can search large and complicated spaces stemmed on the ideas from natural genetics and evolutionary principle (Goldberg, 1989 and Holland, 1975). They have been demonstrated to be effective and robust in searching very large spaces in a wide range of applications (Colin, 1994). GP is basically a GA applied to a population of computer programs (CP). While a GA usually operates on strings of numbers, a GP has to operate on CP. GP allows, in comparison with GA, the optimization of much more complicated structures and can therefore be applied to a greater diversity of problems (Sette and Boullart, 2001). While bankruptcy prediction can be considered as a classification problem, we provide necessary description of GP with emphasis on its application in classification role (Koza, 1992). Genetic programming models were inspired by the Darwinian theory of evolution. According to the most common implementations, a population of candidate solutions is maintained, and after a generation is accomplished, the population is fitted better for a given problem. Genetic programming uses tree-like individuals that can represent mathematical expressions. Such a GP individual is shown in Figure 2.

**Figure 2: Tree representation of the program (expression):**

\[(X \times Y) + 6 - (Z/8)\]
Three genetic operators are mostly used in these algorithms: reproduction, crossover, and mutation. First the reproduction operator simply chooses an individual in the current population and copies it without changes into the new population. In second step two parent individuals are selected and a sub-tree is picked on each one. Then crossover swaps the nodes and their relative sub-trees from one parent to the other. If a condition is violated the too-large offspring is simply replaced by one of the parents. There are other parameters that specify the frequency with which internal or external points are selected as crossover points. Figure 3 and Figure 4 show an example of crossover operators.

**Figure 3: Representation of crossover (parents for mutation)**

![Representation of crossover (parents for mutation)](image)

**Figure 4: Representation of crossover (children from mutation)**

![Representation of crossover (children from mutation)](image)

Also the mutation operator can be applied to either a function node or a terminal node which in the tree is randomly selected. If the chosen node is a terminal node it is simply replaced by another terminal and if it is a function and point mutation is to be performed, it is replaced by a new function with the same parity (Shin and Lee, 2002). When tree mutation is to be carried out,
a new function node is chosen, and the original node together with its relative sub-tree is substituted by a new randomly generated sub-tree. A depth ramp is used to set bounds on size when generating the replacement sub-tree. Naturally it is to check that this replacement does not violate the depth limit. If this happens mutation just reproduces the original tree into the new generation. Further parameters specify the probability with which internal or external points are selected as mutation points. An example of mutation operator is shown in Figure 5.

**Figure 5: Representation of mutation**

The major steps of genetic programming can be summarized as follows:

1. Generate an initial population of rules representing potential solutions to the prediction of the bankrupt and non-bankrupt firms’ classes at random.
2. Evaluate each rule on the training set by means of a fitness function.
3. Select the rules to run the mechanism of reproduction.
4. Apply the genetic operators’ crossover, reproduction and mutation to produce new rules.
5. Reinsert these off-springs to create the new population.
6. Repeat steps (3)–(6) until an acceptable classification rule is found or the specified maximum number of generations has been reached.
7. Repeat steps (2)–(7) until one rule is determined for each class in the database.
8. Assign each example in the training and in the test sets to one and only one class.
The last step for obtaining the best fitness function for all classification problems, in order to be able to apply a particular fitness function, the learning algorithms must convert the value returned by the evolved model into “1” or “0” using the 0/1 Rounding Threshold. If the value returned by the evolved model is equal to or greater than the rounding threshold, then the record is classified as “1” and “0” otherwise (Wu et al., 2007). There are many varieties of fitness function such as number of hits, sensitivity/specificity, relative squared error (RSE), mean squared error (MSE), that can be applied for evaluating performance of generated classification rules. We used “number of hits” as fitness function because of its simplicity and efficiency which is based on the number of samples correctly classified. More formally, the fitness $f_i$ of an individual program corresponds to the number of hits and is evaluated by $f_i = h$ where $h$ is the number of fitness cases correctly evaluated or number of hits. So, for this fitness function, maximum fitness $f_{\text{max}}$ is given by $f_{\text{max}} = n$ where $n$ is the number of fitness cases.

Its counterpart with “parsimony pressure” uses this fitness measure $f_i$ as “raw fitness”, $rf_i$ and complements it with a parsimony term. Parsimony pressure puts a little pressure on the size of the evolving solutions, allowing the discovery of more compact models. Thus, in this case, raw maximum fitness $rf_{\text{max}} = n$ and the overall fitness $f_{\text{pp}}$ that is, fitness with parsimony pressure is evaluated by $f_{\text{pp}} = rf_i \times \left(1 + \frac{1}{5000} \times \frac{S_{\text{max}} - S_i}{S_{\text{max}} - S_{\text{min}}} \right)$ where $S_i$ is the size of the program, $S_{\text{max}}$ and $S_{\text{min}}$ represent minimum and maximum of program population respectively. Maximum and minimum of program sizes are evaluated by the formulas: $S_{\text{max}} = G(h + t)$ and $S_{\text{min}} = G$ where $G$ is the number of genes, and $h$ and $t$ are the head and tail sizes. Thus, when $rf_i = rf_{\text{max}}$ and $S_i = S_{\text{min}}$, with $f_{\text{pp}} \text{max} = 1.0002 \times rf_{\text{max}}$ the process will be optimized. The described procedure is depicted in the flowchart of Figure 6 (Tsakonas, 2006).
Once fitness function is defined, bankruptcy prediction problem becomes a search problem of the best solution in the search space of all the possible solutions, that is to say an optimization of the fitness function for which optimization techniques can be used. The implementation of a genetic model is to automatically extract an intelligible classification rule for prediction classes of bankrupt and non-bankrupt firms in a sample by the given values of some financial ratios, called predicting variables. Each rule is constituted by a logical combination of these ratios. The combination determines a class description which is used to construct the classification rule. Given a number of variables describing each firm and their related domains, it is easy to understand bankruptcy prediction problems by the number of possible solutions obtained which is enormous.
3.2. Dynamic Risk Space (DRS)

In this section, the previous argument is extended and we present a new geometric device named the Dynamic Risk Space (DRS), which allows a visualization of evolution of risk that is associated with ratio values changes.

Consider a square two-dimensional space that captures all changes in numerator (X) and denominator (Y) for any firm $i$, for any period where changes in X ($\Delta X$) and Y ($\Delta Y$) can be positive, negative or zero$^1$. Let the risk flows for any hypothetical firm $i$ consist of the set of all $(\Delta X)$ and $(\Delta Y)$ for $n$ years $\forall t = 1, 2, 3, ..., n$. Ratio values are usually available at uniform (discrete) time intervals, annually, quarterly.

The dimensions of the DRS are central with respect to $\max(\Delta X)$ and $\max(\Delta Y)$ which will be derived in next section. The essential ingredient is that the length of any side is set at two times the maximum of largest absolute changes value of whichever is bigger from the numerator and denominator values recorded during the considerable period.

Correspondingly, the total area of DRS is $2 \times \max(\max|\Delta X_t|)^2$ if the largest absolute value is Book value or $2 \times \max(\max|\Delta Y_t|)^2$ if the largest value is Market value. Book values are depicted on the vertical axis ($\pm\Delta Y$) and Market values on the horizontal axis ($\pm\Delta X$) as labeled in Figure 7. The actual value depends on which of the two is largest, and this value is then applied to both axes to ensure a perfect square.

---

1. It is applicable for any level of aggregation such as cross-country studies, cross sector, and ratios.
Consider the location of an arbitrary risk change co-ordinate \((\Delta X, \Delta Y)\), the upper and lower triangles \(\triangle ABC\) and \(\triangle ADC\) define as the Net Risk for \(Y\) (\(NR_Y\)) and Net Risk for \(X\) (\(NR_X\)) respectively. The axes are labeled in accordance with the Cartesian plane so the DRS consist of four quadrants I-IV. The origin represents the unique \([0, 0]\) case. Quadrant I contains all positive and quadrant III all negative changes. Quadrant II consists of negative \(X\) and positive \(Y\), while quadrant IV contains negative \(Y\) and positive \(X\). The \(45^\circ\) and \(AOC\) line is that of perfectly matched risk changes and zero net values. Following our definition, lines parallel to the \(45^\circ\) and \(AOC\) line are termed risk lines. This line with positive slope diagonal is the locus of balanced risk where \(\Delta X = \Delta Y\) and DRS equals zero. This will illustrate the risk symmetry component axis.

For any points such as J, K and L in Figure 2, on a same dynamic risk line share equal risk values and K with higher risk compared to J and L. According to Figure 2, Y values will fall and X values will remain unchanged in period K in comparison to J, while X values will rise and Y values will remain unchanged in period K to L. For any point such as J or K away from the \(AOC\) line, the greater is the risk.

Assume that (i) changes are a monotonically increasing function and (ii) that risk values requirements for both X values and Y values are equal. A
A measure of dynamic risk space that satisfies criteria (I)-(IV) for \( n \) years i.e. \( \forall t = 1, 2, 3, ..., n \) is given by:

\[
DRS_i = \frac{1}{2L} (\Delta X_i - \Delta Y_i) = \frac{\Delta X_i - \Delta Y_i}{2(\max\{\max|\Delta X|_n, \max|\Delta Y|_n\})^2}
\]

where \( L \) is the length of one side of a DRS. The index range is \(-1 < DRS < 1\).

For example to illustrate the implication and applicability of this method consider \( \frac{\text{cash flow}}{\text{total assets}} = \frac{CF}{TA} \) as an example of ratio which is mostly been used in studies. In our methodology \( DRS_i = \frac{\Delta CF_i - \Delta TA_i}{2(\max\{\max|\Delta CF|_n, \max|\Delta TA|_n\})^2} \) will be imposed on the transformation of this ratio.

The values for this equation will be \(-1 < DRS < 1\), and in more details is explained bellow:

- If \( CF > TA \), means that the changes in cash flow are more than changes in total assets and DRS will be in positive form, if \( 0 < DRS < 1 \), then in this case, the companies with higher cash flow will be stronger. This is in a case of short term, which is the focus of our study. However in long term, the company may be affected by liquidity.

- If \( CF < TA \), means that changes in total asset is more than changes in cash flow and DRS will have negative values, if \( -1 < DRS < 0 \), then the company is more likely to fail. Meaning that more assets in company are not retaining higher earning which will cause more cash outflow. Additionally, the investment is not productive enough and these companies are more likely to go bankrupt.

One of the primary innovations of the DRS index is the scaling factor that stems directly from the DRS construction and is two times the absolute maximum of the largest change for the period of study equivalent to \( 2L^2 \) in Figure 2. Note that the \( \Delta X \) or \( \Delta Y \) value in the denominator and numerator will only be equal when either \( \Delta X \) or \( \Delta Y \) is also the largest change during
the period of study. Consider again the proposed measure of Dynamic Risk Space, \( DRS = \frac{\Delta X - \Delta Y}{2(\max \{ \max |\Delta X|, \max |\Delta Y| \})^2} \), that can be rewritten as:

\[
DRS = \frac{\Delta X}{2(\max \{ \max |\Delta X|, \max |\Delta Y| \})^2} - \frac{\Delta Y}{2(\max \{ \max |\Delta X|, \max |\Delta Y| \})^2}
\]

Thus, this shows that for every DRS index, there exists a unique straight line with slope of unity and \( \alpha \) intercept. The multiplication of two factors i.e. \( 2(\max \{ \max |\Delta X|, \max |\Delta Y| \}) \times (DRS)^2 \) implies that DRS values will be the same for every point \((\Delta X, \Delta Y)\) on the same line.

Consider again, \( DRS = \frac{\Delta X - \Delta Y}{2(\max \{ \max |\Delta X|, \max |\Delta Y| \})^2} \) in which \( f(\Delta X, \Delta Y) \) and the function of \((-\Delta X, -\Delta Y)\) is:

\[
f(-\Delta X, -\Delta Y) = \frac{-\Delta Y - (-\Delta X)}{2(\max \{ \max |\Delta X|, \max |\Delta Y| \})^2} = \frac{\Delta X - \Delta Y}{2(\max \{ \max |\Delta X|, \max |\Delta Y| \})^2} = f(\Delta X, \Delta Y)
\]

This shows that DRS index is symmetric about the diagonal \( \Delta X = -\Delta Y \). Respectively, scaling by the largest value for a given time scale (that could be months, years or even decades) allows us to observe the progress of risk changing over time.

Now consider the equations \( DRS = \frac{\Delta X - \Delta Y}{2(\max \{ \max |\Delta X|, \max |\Delta Y| \})^2} = \frac{\Delta X - \Delta Y}{2L^2} \). This means that for partial presentation we will have:

\[
\left( \frac{\partial DRS}{\partial \Delta X} \right) = \frac{1}{2(\max \{ \max |\Delta X|, \max |\Delta Y| \})^2} \quad \text{and} \quad \left( \frac{\partial DRS}{\partial \Delta Y} \right) = \frac{-1}{2 \max \{ \max |\Delta X|, \max |\Delta Y| \})^2}
\]

which can verify the rate of changes of DRS in the upper sector of Figure 2 in which \( \left( \frac{\partial DRS}{\partial \Delta Y} \right) \) is similar but opposite to that in the lower sector of \( \left( \frac{\partial DRS}{\partial \Delta X} \right) \).

Hence, the DRS index exhibits proportional scaling. The usually stated requirement in controlling for size is that the numerator and the denominator of a financial ratio have to be proportional.
According to the matters discussed above when using this proposed DRS index to measure the changing levels to have it summed at a disaggregated level, we have to choose the appropriate weights to measure the changes. The solution is the index to be weighted by the significance of the sector. Let

\[
D_{RS_i} = \frac{1}{2L^2} (\Delta X_i - \Delta Y_i) = \frac{\Delta X_i - \Delta Y_i}{2(\max\{\max|\Delta X|_n, \max|\Delta Y|_n\})^2}.
\]

The weighted \(D_{RS_i}\) is:

\[
D_{RS_{wi}} = D_{RS_i} \times \frac{1}{2L^2} (\Delta X_i - \Delta Y_i) = D_{RS_i} \times \frac{\Delta X_i - \Delta Y_i}{2\sum_i (\max|\Delta X|_n, \max|\Delta Y|_n)^2}
\]

and the summarized format will be \(D_{RS_{wi}} = D_{RS_i} \times \frac{L}{2 \times (\sum_i L_n)^2}\). It is interesting to note that this formulation enables us to have a multilayered view of changes of each value of ratio. Thus \(D_{RS_n}\) as the top most layers will encapsulate all the \(D_{RS_i}\) cells.

The properties that have derived may be used as general guidelines for ratios analysis, in which there is no arbitrary conditioning because the number of transformations is equal to the number of observations. Furthermore, the natural distributions of SR and DRS transformations ensure that data are not skewed and should be more robust (the assumptions of Gaussian statistical methods). In addition, SR and DRS can be applied equally to a variety of distributional forms, thus making the technique particularly useful in ratio analysis where a diverse set of distributional functions has to be identified. Moreover, the new ratio transformation of DRS is naturally bounded and unaffected by distance between observations, resulting the outlier effect to be reduced. Similarly, this method can be extended to the data contains white noise where the sensitivity and power of statistical test are likely to improve. In addition, proportionality is a theoretical assumption that may not in fact hold and the degree of departure varies across industries and size classes. Thus if the relationship between elements of a ratio be constant over time, size and industry, then the proportionality effect will be satisfied for ratios. Finally, by using pooled data across time, the DRS method will reduce effects of history and maturation to the extent these are present across population. In the other hand, negative values will be naturally transformed to specific variation and distance \(\gamma\) using these transformations, thus removing the necessity of deletion of
negative data used in previous studies. As may be observed from the prediction results in Section 4, we suggest the use of Dynamic Geometric Genetic Programming (DGGP) methodology for financial variables analysis, which provide a conceptual and complimentary methodological solution to many problems associated with the use of common ratios.

4. Illustrative Empirical Application

The data set used in our illustrative empirical study consists of 350 Iranian companies from Tehran Stock Exchange (TSE) by 100 companies went bankrupt under paragraph 141 of Iran trade law and 250 companies are "matched" companies in the same period of listing from 1990 to 2005. In this study, bankrupt companies are indicated as 1 and non-failed companies as 0.

To construct our bankruptcy prediction model, the data is divided into two sets, the training and the test sets. The training set contains the known firms used during the evolution process to find an explicit classification rule which is able to separate an instance of a class of bankrupt firms from instances of non-bankrupt class (De Falco, Della Cioppa, & Tarantino, 2002). In contrast, the test set is used to evaluate the generalization ability of the rule found. Thus, we used 80% of sample data for training and the remaining 20% for testing sample for each analysis. Training samples consists of 280 firms including 80 bankrupt and 200 non-bankrupt for both approaches and holdout sample contains 70 firms consisting of 20 bankrupt and 50 non-bankrupt firms which are shown in Table 1.

| Table 1: Number of firms used in the study for training and testing samples |
|--------------------------|------------------|-----------------|
|                         | Training | Testing | Total  |
| Bankrupt                | 80       | 20      | 100    |
| Non-bankrupt            | 200      | 50      | 250    |
| Total                   | 280      | 70      | 350    |

According to availability of data and popularity of ratios, 40 ratios are constructed and introduced as indicators for financial analysis as in Table 2.

---

1. Under paragraph 141 of Iran Trade Law, a firm is bankrupt when its total value of retained earnings is equal or greater than 50% of its listed capital.
Table 2: Variables comparison of means in two groups

<table>
<thead>
<tr>
<th></th>
<th>Definition of variables</th>
<th>Means of non-bankrupt companies</th>
<th>Means of bankrupt companies</th>
<th>TEGM (Sig level)</th>
<th></th>
<th>Definition of variables</th>
<th>Means of non-bankrupt companies</th>
<th>Means of bankrupt companies</th>
<th>TEGM (Sig level)</th>
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BVD: Book Value of Dept  
CA: Current assets  
EAIT: Earning after income and taxes  
GP: Gross profit  
Inv: Inventory  
MVE: Marked value of equity  
NI: Net income  
OI: Operational income  
QA: Quick assets  
RE: Retained earnings  
SC: Stock capital  
TA: Total assets  
TL: Total liabilities  
TEGM: Test of equity of group mean  

Ca: Cash Flow  
CL: Current liabilities  
EBIT: Earnings before interest and taxes  
IE: Interest expenses  
LA: Liquid assets  
NFA: Net Fixed assets  
OA: Operating asset  
POC: Paid on capital  
R: Receivables  
S: Sales  
SE: Shareholders’ equity  
TD: Total debt  

* Selected variables by CartXpr software.
Since one and two year prior to bankruptcy is much important for predictions, this new method was performed by using changes in the form of two annual reports $t$ and $t-1$ for each company and each ratio can satisfy the firm’s performance observation within two years.

For variable selection and testing effectiveness of each variable on discriminating power, CartProEx V.6.0 software with Mahalanobis $D^2$ test with 5% significance level was used to select variables which produce greatest effectiveness on separation for two groups to have more stable and well-balanced model.

5. Results

Following recent research by Bahiraie et al. (2011) and Etemadi et al. (2008) we tested these selected variables with Genetic Programming (GP) to obtain fitness function tree and to illustrate that this new transformation will predict more accurate and can be used as an alternative for common ratios. In the final regressions with fewer significant variables in different classification trees where as expected and we observed that different variables were identified as significant indicators for each procedure from the selected list. For implementing GP process and developing bankruptcy model, GeneXproTools software version 4.1 was used. Crossover and mutation operators were set as 0.44 and 0.05 respectively.

Figures 8 and 9 show the best GP model obtained for each approach. These models have been divided in three sub-trees in which each tree representing a Gene meaning the model is a chromosome consisting of tree genes. Sum of the returns of sub-trees for a firm should be compared with “Rounding Threshold” for determining the class of the firm.
From the classification sub-trees depicted in Figure 8, d0, d1, d2, d3, d4, d5 and d6 are equal to the selected transformed variables (TX) as input variables which are TX15, TX24, TX35, TX25, TX27, TX32 and TX8 respectively. These variables are found to be significant effective in decision trees for DRS approach with 95.14% obtained accuracy rate.
From the classification sub-trees in Figure 9, $d_0$, $d_1$, $d_2$, $d_3$, $d_4$, $d_5$ and $d_6$ are equal to the selected common ratios (X) as input variables which are $X_{27}$, $X_{35}$, $X_{25}$, $X_{24}$, $X_{7}$, $X_{4}$ and $X_{14}$ respectively. These variables are found to be significant in decision trees for common ratios approach with 88.85% accuracy level. The representation of a solution for the problem provided by the GP algorithm is in the form of decision sub-tree. Each node of this tree is a function node taking one of the values from the set $+$, $-$, $*$, $^\wedge$, EXP and etc. Some of operators which were used in our study are shown in Table 2:
Table 3: Function nodes reported in decision trees in figures 8 and 9

<table>
<thead>
<tr>
<th>Representation</th>
<th>Name</th>
<th>Representation</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>Addition</td>
<td>Exp</td>
<td>Exponential</td>
</tr>
<tr>
<td>-</td>
<td>Subtraction</td>
<td>E</td>
<td>e</td>
</tr>
<tr>
<td>*</td>
<td>Multiplication</td>
<td>Pi</td>
<td>II</td>
</tr>
<tr>
<td>/</td>
<td>Division</td>
<td>Log</td>
<td>Logarithmic</td>
</tr>
<tr>
<td>Sin</td>
<td>Sine</td>
<td>Asin</td>
<td>Arcsine</td>
</tr>
<tr>
<td>Cos</td>
<td>Cosine</td>
<td>Acos</td>
<td>Arccosine</td>
</tr>
<tr>
<td>Tan</td>
<td>Tangent</td>
<td>Atan</td>
<td>Arctangent</td>
</tr>
<tr>
<td>Cot</td>
<td>Cotangent</td>
<td>Acot</td>
<td>Arc cotangent</td>
</tr>
<tr>
<td>Sec</td>
<td>Secant</td>
<td>Asinh</td>
<td>Arcsine hyperbolic</td>
</tr>
<tr>
<td>Csc</td>
<td>Cosecant</td>
<td>Acosh</td>
<td>Arccosecant hyperbolic</td>
</tr>
<tr>
<td>Sinh</td>
<td>Sine hyperbolic</td>
<td>Atanh</td>
<td>Arctangent hyperbolic</td>
</tr>
<tr>
<td>Cosh</td>
<td>Cosine hyperbolic</td>
<td>Acoth</td>
<td>Arc cotangent hyperbolic</td>
</tr>
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<td>Arc cosecant hyperbolic</td>
<td>Csch</td>
<td>Cosecant hyperbolic</td>
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<tr>
<td>Asech</td>
<td>Arc secant hyperbolic</td>
<td>Sech</td>
<td>Secant hyperbolic</td>
</tr>
<tr>
<td>4RT</td>
<td>X^1/4</td>
<td>X3</td>
<td>X^3</td>
</tr>
<tr>
<td>5RT</td>
<td>X^1/5</td>
<td>X4</td>
<td>X^4</td>
</tr>
</tbody>
</table>

For decision making of bankrupt or non-bankrupt firms through the genetic programming decision tree, a benchmark value of 0.5 is used. If the value for specific training or test firm is greater or equals 0.5, then this firm is marked as “bankrupt firm”. If the value of the GP model for a training or test firm is less than 0.5, then this firm is classified as “non-bankrupt firm”. In the training and testing sample for each approach, comparison of real class of firms with predicted class by the GP model will determine the accuracy of the model as reported in Table 4.

Table 4: Genetic Programming accuracy levels for transformed and original ratios

<table>
<thead>
<tr>
<th></th>
<th>Training sample</th>
<th>Holdout sample</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original Ratios</td>
<td>90.71 %</td>
<td>81.42 %</td>
<td>88.85 %</td>
</tr>
<tr>
<td>Transformed Ratios</td>
<td>95.71 %</td>
<td>92.85 %</td>
<td>95.14 %</td>
</tr>
</tbody>
</table>
Table 4 exhibits the summary of overall accuracy levels for GP procedures. The levels of accuracy improved under data transformation approach for both training and testing samples. Due to better performance testing of this new transformation, data set collected do not have to be in a particular industry type or similar firm size and application of outlier deletion method to overcome any potential explanatory effect errors that will be caused by independent variables distribution\(^1\) is not necessary to accomplish the new model properties as explained in methodology. In this study, the number of hits as described in the previous section was used as the fitness function and for testing predictive power of model, data set was randomly separated into training and testing groups.

**Table 5: Results of Genetic Programming models**

<table>
<thead>
<tr>
<th></th>
<th>Training</th>
<th></th>
<th>Testing</th>
<th></th>
<th>Total</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>□</td>
<td>☐</td>
<td>□</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>DRS</td>
<td>Bankrupt</td>
<td>76</td>
<td>4</td>
<td>18</td>
<td>2</td>
<td>94</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Non-Bankrupt</td>
<td>192</td>
<td>8</td>
<td>47</td>
<td>3</td>
<td>239</td>
<td>11</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>266</td>
<td>12</td>
<td>65</td>
<td>5</td>
<td>329</td>
<td>17</td>
</tr>
<tr>
<td>Ratios</td>
<td>Bankrupt</td>
<td>73</td>
<td>7</td>
<td>15</td>
<td>5</td>
<td>88</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Non-Bankrupt</td>
<td>181</td>
<td>19</td>
<td>42</td>
<td>8</td>
<td>223</td>
<td>27</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>254</td>
<td>26</td>
<td>57</td>
<td>13</td>
<td>341</td>
<td>39</td>
</tr>
</tbody>
</table>

**☐: Correctly classified □Wrongly classified**

From Table 5, the GP model has achieved 95.71% and 92.85% accuracy rates in transformed training and holdout samples respectively whereas original ratios model achieved only 90.71% and 81.42% accuracy rates in training and holdout samples respectively.

\(^1\) Deakin (1967) found that financial ratios might be more normally distributed within a specific industry groups.
6. Conclusion

Since the global increases of bankruptcies, studies for accurate predictions of companies' distress and bankruptcies have been extensive. One of the most well-known anomalies of the risk factors is the effect of some ratios on bankruptcy risk and firm returns. The use of financial ratios may exceed cost of errors in analysis caused by ratio-related model miss-specification, and in general, no equally convenient or superior alternative to untransformed ratios has been developed and applied to financial ratio analysis. Hence, this research was motivated to develop an alternative ratio-based methodology for financial studies.

As demonstrated, this paper presents a complementary perspective on risk analysis and bankruptcy prediction with the use of financial ratios. In this paper, a new dimension to risk measurement, bankruptcy, and ratio transformation is realised with the advent of the Dynamic Risk Space (DRS). We briefly derived the respective properties of new risk approach components of which can overcome the use of common ratios limitations. Our simple methodology, called DRS index, provide a geometric illustration of our new proposed risk measure and transformation behavior.

Our study employed 100 distressed companies with matched sample of another 250 non-failed companies listed in Tehran Stock Exchange (TSE). We found a rise in classification accuracy with the application of this new independent variables transformation using genetic programming (GP) technique as a statistical prediction model compared to input common ratios as independent variables. The GP model was 95.14% and 88.85% accurate on transformed and common ratios samples respectively.

According to proven properties of new DRS method discussed with better numerical results obtained, it is strongly suggested the use of this new methodology for ratio analysis, which provided a conceptual and complimentary methodological solution to many problems associated with the use of ratios. Alternatively, the dynamic risk space model (DRS) can be employed as a tool of analysis in providing a crucial first stage for analysing studies associated with changes in risk patterns, in particular those assumed to be linked with potential bankruptcies. The novelty of this proposed
methodology is emphasised by its applicability for any number of years on sectoral or cross-country data on risk and bankruptcy studies.

Since previous studies used one and two year prior to bankruptcy, this new method uses changes in the form of two annual report of each company and can satisfy the firm’s performance observation within these two years. Consequently, to generalize the ability of the model with expansion for an additional year is recommended for further studies.

Furthermore, as reported by IMF, to undertake such research to understand the capital structures and other financial indicators such as macro and micro economic variables simultaneously that might affect firms’ performance and eventually can improve prediction is necessary, therefore testing this model with respect to this issue will be important and need to be continued.
References


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Financial Stability in Islamic Banking System; the Capacity to React to Current World Wide Crisis

Parastoo Shajari*  
Bita Mohebikhah**

Abstract

This paper investigates the financial stability, measured by z-score technique in Islamic banking system of 20 countries from 2000 to 2010. We compare the stability of Islamic banks to the commercial banks, before and after the financial crisis. The empirical results from panel estimation show that: a) the large Islamic banks are more stable than the large commercial banks and furthermore, the small Islamic banks have lower z-score comparing to the small commercial banks. b) as past history shows, in general the financial crisis has a direct negative impact on stability of the large banks; moreover, our study shows that after a financial crisis the small Islamic banks are more stable than large Islamic banks. c) there is no significant difference between stability in oil and non-oil producing countries, however results change between the small and large banks in the two groups of Islamic and commercial banks which tend to be more stable for oil producing countries.

Key words: Islamic banks, Financial stability, Financial crisis, Oil Producing Countries

GEL Classification: G21, G33.

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** Expert of Economics in Ministry of Communication and Information Technology.
I. Introduction

Our aim is to analyze the strength of Islamic banks compared to conventional commercial banks using the data for 429 banks, including 113 Islamic banks and 316 commercial banks, in 20 countries, from 2000 to 2010. In order to examine the stability more precisely, we separate our period of study to before and after financial crisis and also our countries in two groups of oil and non-oil countries.

In recent decades, especially after the recent financial crisis, financial stability is considered as an important economic objective more than ever. According to the different sources, financial stability is not measured any more by only one criterion and there are different analytical frameworks for assessing financial system stability.

Financial stability system have five principal features, firstly financial stability is a broad concept including the different aspects of finance infrastructure, institutions, and markets. Secondly, financial stability not only involves adequate allocation of resources and risks such as mobilizing savings, and facilitating wealth accumulation, development, and growth, actually financial stability is a more comprehensive concept and it should also imply that the systems of payment throughout the economy function smoothly. Third, the absence of actual financial crisis can’t be considered as financial stability. The important is the ability of the financial system to limit, contain, and deal with the emergence of imbalances before they constitute a threat to itself or economic processes. Fourth, instabilities in financial markets or in individual financial institutions, those not lead to larger turbulence in financial system and are not expected to damage economic activity, could not be considered as financial stability. Fifth, according to the actual dynamism of finance, financial stability should be considered as occurring along a continuous sequence (Schinasi. G 2004). In fact, stability in the financial system can be achieved through the adequate resource allocation, risk identification and assessment, appropriate risk management and also considering the external shocks. Another definition of financial stability can be provided through the proper performance and stability of all components of a financial system. Evidence shows that the financial crisis occurs when the macroeconomic structure is weak, the rate of inflation is
high or economic growth is low and in this situation banks are considered one of the main objects of the financial crisis.

Banking crisis and the bankruptcy has at least two major effects on the economy: shareholders lose their investment and the depositors will lose their savings. Typically, these crises start in one or more banks and then affect the entire economy. It also can spread to the other banks and financial markets in other countries, if one bank gets into the critical condition, this could spread to the whole banking system. Therefore, the confidence in the performance of domestic financial institutions reduces banking crisis. One of the most prominent signs of bank crisis is when the bank run happens and the bank has difficulty to repay its debts. The causes of banking crisis can be classified in 7 groups: 1. Vulnerability of bank performance and systematic risk 2. Financial liberalization programs, 3. International shocks, 4.Currency regimes and exchange rate fluctuations, 5.Bank’s structure and ownership, 6.The role of official authorities, 7. Associated political systems.

There are many debates comparing the performance of Islamic banks and the conventional banks. Choong and Liu (2006) discuss that Islamic banking, in the case of Malaysia, deviates from the PLS paradigm, and in practice is not very different from conventional banking. They propose that in order to analyze the financial sector, Islamic banks should be treated similarly to their commercial counterparts. Cihak and Hess (2008) analyze the relative financial strength of Islamic banks based on evidence covering 18 countries with 77 Islamic banks and 397 commercial banks over the period 1993 to 2004. They find that the small Islamic banks tend to be financially stronger than the small commercial banks which may reflect challenges of credit risk management in the large Islamic banks. Inversely, the large commercial banks tend to be financially stronger than large Islamic banks. The small Islamic banks tend to be financially stronger than large Islamic banks.

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2. In 2007 they also analyzed the role of cooperative banks in financial stability. Cooperative banks are an important and growing part of many financial systems. They found that cooperative banks are more stable than commercial banks due to the lower volatility of the cooperative banks’ returns, which is more than offsets their lower profitability and capitalization. They also found that in systems with a high presence of cooperative banks, weak commercial banks are less stable than they would be otherwise.
After the recent financial crisis, debates have been raised about the performance of Islamic banks during the crisis period. There is nearly no practical analysis which has studied the performance of Islamic banking system during the recent financial crisis. The recent financial crisis has started from the problems in the United States with home loans\(^1\), mortgages and complex interplay of liquidity problems in the United States' banking system in 2008, followed by the sharp spear to other banking systems all around the world.

In this area there are so many questions to be asked: how this financial crisis affected Islamic banks? What are the reactions of Islamic banks to this crisis? Is there any significant difference between Islamic banks and commercial banks facing this crisis? And finally, do Islamic banks have more stability experience than commercial banks? This article tries to analyze the situation of Islamic banks, before and after the financial crisis comparing to commercial banks.

Our results show that the large Islamic banks are more stable than the large commercial banks. The financial crisis has negative impact on stability of the large banks and there is no significant difference between stability in oil and non-oil countries.

This paper is developed in four sections: Section II has a brief overview of the features of Islamic banking and has reviewed the related literature. Section III discusses the measurement of financial stability. Section IV presents the methodology and section V discusses the results of our regression estimations. Finally, section VI summarizes the conclusions.

II. The Principles of Islamic Banking

There is a set of general values of ethic underpinning Islamic finance. Based on the principal and foundation laid down by Shari'ah, there are 5 ethical principles related to banking system: 1. Avoid Reba 2. Avoid Gharar 3. Honesty and fair trade 4. Avoid selling forbidden items (haram) like alcoholic beverages or pork, non-Islamic media, and gambling operations 5. Follow goal of social justice. In addition to the goals of social

\(^1\) Sub-prime loans.
justice which is one of the most important issues in Islamic banking, there are three main differences between conventional and Islamic banks; first the Islamic banks have more than financial intermediary role and they have also responsibility as a fund manager. The bank is responsible for identifying the right project to participate, in order to achieve its goals. Second, Islamic bank manages its activities base on the real part of economy, regarding to size of growth in each part. Third, the important difference is that the depositors are not lenders or creditors, they are investors. This means that an Islamic deposit has equity-like characteristics. In fact Islamic banking system works on the basis of profit-and-loss sharing (PLS) arrangement. Reba is forbidden and Islamic financial services are known as a prohibition against the payment and receipt of interest at a fixed or predetermined rate. In the PLS arrangement the return on assets is not fixed before the transaction.

The PLS agreement changes the risk features in banking system. It increases the overall degree of risk on the asset side of banks’ balance sheets and transfers the direct credit risk from banks to their investment depositors. This makes Islamic banks fragile to risks from the equity investors’ side rather than holders of debt. Operational risk is the risk of loss resulting from inadequate or failed internal processes, people and systems or from external events. This risk associated with administration of PLS, can be more complicated in Islamic banks in comparison with conventional banks. Consequently, this risk is crucial for Islamic banks. Some risk hedging instruments are limited in Islamic banks. PLS could be accepted as an agreement without any collateral or guarantees in order to reduce credit risk. Another important risk related to Islamic banks is coming from the nature of investment deposits, when capital value and return are not guaranteed. This could increase the probability of moral hazard [Sundararajan and Errico (2002); Iqbal and Llewellyn (2002)].

In Islamic banks the source of fund is defined in three categories, as follows (M. Ikram Thowfeek):

Murabaha (Mark–up financing): The seller informs the buyer of his cost of acquiring or producing a specified product. The sale is immediate and it is conditional upon future events. In Murabaha, the buyer knows the seller’s
price and the profit is declared as a single mark up. A Murabaha may be executed directly with the bank as buying principal in the deal, or indirectly with the third party making the purchase as an agent (Wakil) for bank. The profit margin is negotiated between them and the total cost is usually paid in installments.

Musharaka (Equity participation): Musharakah is one of the most important concepts in Islamic banking. Musharakah is a relationship between two parties and is more than contributing capital to a business and share the net profit and loss. This contract is often used in investment projects, letters of credit, and the purchase or real estate or property and the provision of capital and management by both bank and customer.

In the case of real estate or property, the banks assess an imputed rent and will share it as agreed in advance. All providers of capital are entitled to participate in management, but not necessarily required to do so. The profit is distributed among the partners in pre-agreed ratios, while the loss is borne by each partner strictly in proportion to respective capital contributions. This concept is distinct from fixed-income investing¹.

Ijara (Lease, lease purchase): For the whole period of lease, the rental must be determined at the time of contract. It has permitted different amounts of rent to be fixed for different phases during the lease period, provided that

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the amount of rent for each phase is specifically agreed upon at the time of affecting the lease.

Istisna (Deferred payment, deferred delivery): ‘Istisna’ is the second kind of sale where a commodity is transacted before it comes into existence. A manufacturer agrees to produce and to deliver a certain good at a given price on a given date in the future. In fact it is necessary to fix the price with the consent of the parties and it is also necessary to define the specification of the commodity. The price does not have to be paid in advance. It may be paid in installments or part may be paid in advance with the balance to be paid later on, based on the preferences of the parties.

Salam (Pre-payment, deferred delivery): Salam is a sale whereby the seller undertakes to supply some specific goods to the buyer at a future date in exchange of an advanced price fully paid at spot. Here the price is cash, but the supply of the purchased goods is deferred. Salam is beneficial to the seller, because he receives the price in advance, and it is beneficial to the buyer also, because normally, the price in salam used to be lower than the price in spot sales.

Ju’ala (Service charge): A party offers specified compensation to anyone who will achieve a determined result in a known or unknown period, based on a specified amount of money as a fee for paying a service due to the terms of contract. This contract typically is used in transactions such as consultations & professional services, fund placements and trust services.

Qard Hassana: Qard Hassana (Beneficent loans) means beneficial loan, gratuitous loan, interest free loan. Banks are permitted to charge borrowers a service fee, regarding to loans amount or maturity, to cover the administrative expenses of handling the loan.

Mudaraba (Trustee finance contract): Is a contract whereby one side (the investor) or Rabb ul Mal contributes money and the other side work, (being the manager or Mudarib). Profits are shared between them at a certain fixed ratio, whereas financial losses are exclusively borne by rabb -ul- mal. Mudaraba is a concept to provide capital to somebody undertaking the work. It could be understood as being similar to the function of an asset manager or employed manager of a company.
The risk concept is different in Islamic banks from conventional banks and this can be analyzed from different point of views. Seref Ture (1996) argues three Main reasons for the risks in Islamic banks. Firstly, the deposit holders are not permitted to receive a fixed interest rate but are going to share the profit with Islamic bank due to the Islamic contract agreement. Theoretically, depositors’ money is considered as equity. In Islamic banks when the depositors are transformed to suppliers of equity of the bank, the risk level in Islamic banks decreases because of reduction in financial leverage ratio (debt/equity). The low financial leverage indicates a low level of fixed interest payments to creditors, with small variations in net profit and earnings per share. Therefore, standard deviation of profit or profitability, as a measure of the risk of Islamic bank declines continuously. Second factor is dependence on the net operating income over interest charges (level of the coverage of interest charges ratio). In Islamic banks the fixed interest rate is minimized or completely eliminated. In this situation the bank can be safer because the absence of interest charges ratio, lowers the degree of financial leverage. The third factor of the risk is due to Islamic concept of partnership and profit sharing (Mudarabah). Based on the profit sharing and increasing loans, the profits may be volatile and the risk of the loan portfolio could be increased. Consequently, this will make Islamic banks riskier than conventional banks.

Cihak and Hess also argue that the risk-sharing arrangements on the deposit side provide another layer of security to the bank. This needs to have precise arrangement for stable and competitive return to investors, the shareholders’ responsibility for operational risk. Islamic banks could be more conservative, because the more difficult access to liquidity puts pressures. Islamic bank has more motivations to monitor and supervise the bank management, because investors (depositors) share in the risks. They also notify that usually Islamic banks hold larger proportion of their assets regarding to commercial banks in reserve accounts. Therefore, the riskier investment in these banks might have higher level of buffers.

The credit risk is one of the most important risks which banks can face. This risk in Islamic bank also can appear in different forms through Islamic
contracts. Murabaha and Istisna are sales with delayed payment so they can make debts in the accounts of the banks. Mudarabah and Musharakah as contracts of participation, also bear a credit risk. On one hand, the entrepreneur is liable to guarantee the capital which means a debt liability. On the other hand, bank bears an indirect credit risk when the capital of Mudarabah or Musharakah is employed in a delayed sale. Salam also involves credit risk and raises the commodity debt rather than a cash debt.

Samad's (1999) comparison of conventional and Islamic banks shows that the risk indicators are lower in Islamic banks because its investment in government securities is much larger than conventional banks. The profit and loss sharing modes can bring higher credit risk for Islamic banks. Khan and Ahmed's (2001) study on Islamic financial institutions in 28 countries, shows that the credit risk is the highest in Musharakah (3.69 from a score of 5) followed by Mudarabah (3.25).

Sundararajan and Errico (2002) indicate that appropriate risk managing in Islamic banks needs adequate capital and reserves, appropriate pricing and control of risks, strong rules and practices for governance, disclosure, accounting, and auditing rules, and an infrastructure that facilitates liquidity management. They argue that PLS modes may shift the direct credit risk of Islamic banks to their investment depositors; they may also increase the overall degree of risk of the asset side of banks’ balance sheet. They also discuss that several factors could make Islamic banks less vulnerable to risk comparing to conventional banks because Islamic banks are able to pass through a negative shock on the asset side (like a Musharaka loss) to the investment depositors (like Mudaraba arrangement).

1. They didn’t do the empirical test.
Figure 1: Number of Islamic banks regarding to their size of assets (2010)

![Pie chart showing the distribution of Islamic banks based on their size of assets.]

Table 1: Share of five principal indicators in Islamic banks to total banking system (%), (2010)

<table>
<thead>
<tr>
<th>Countries</th>
<th>Loans</th>
<th>Net Income</th>
<th>Deposit</th>
<th>Equity</th>
<th>Asset</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUDAN</td>
<td>40.65</td>
<td>54.98</td>
<td>52.17</td>
<td>55.99</td>
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<tr>
<td>YEMEN</td>
<td>33.23</td>
<td>9.62</td>
<td>33.11</td>
<td>49.92</td>
<td>39.21</td>
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<td>KUWAIT</td>
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<td>20.56</td>
<td>28.39</td>
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<td>BAHRAIN</td>
<td>26.5</td>
<td>-</td>
<td>22.91</td>
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<td>23.48</td>
</tr>
<tr>
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<td>SAUDI ARABIA</td>
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<td>14.92</td>
<td>29.59</td>
<td>18.35</td>
</tr>
<tr>
<td>UNITED ARAB EMIRATES</td>
<td>18.94</td>
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<td>16.63</td>
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<td>5.82</td>
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<td>4.34</td>
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<td>PAKISTAN</td>
<td>3.48</td>
<td>0.98</td>
<td>4.77</td>
<td>5.25</td>
<td>4.74</td>
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<td>EGYPT</td>
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<td>4.14</td>
<td>3.23</td>
<td>3.92</td>
</tr>
<tr>
<td>BANGLADESH</td>
<td>4.27</td>
<td>1.68</td>
<td>3.79</td>
<td>1.33</td>
<td>3.51</td>
</tr>
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<td>TURKEY</td>
<td>4.96</td>
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<td>3.2</td>
</tr>
<tr>
<td>TUNISIA</td>
<td>1.09</td>
<td>2.8</td>
<td>1.76</td>
<td>1.62</td>
<td>1.46</td>
</tr>
<tr>
<td>INDONESIA</td>
<td>0</td>
<td>0.24</td>
<td>0.48</td>
<td>0.25</td>
<td>0.41</td>
</tr>
<tr>
<td>LEBANON</td>
<td>0.05</td>
<td>-0.6</td>
<td>0.09</td>
<td>0.96</td>
<td>0.18</td>
</tr>
<tr>
<td>SINGAPORE</td>
<td>-</td>
<td>-0.43</td>
<td>0.02</td>
<td>0.32</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Note: In Iran all banks are Islamic. Source: authors, based on Bank Scope

Sudan's banking system has the highest share of Islamic banks comparing to the other countries in the above table. The second place belongs to Yemen, expect the net income.
Figure 2: Four financial indicators in Islamic banks (2002-2010),
Base year = 2002

Source: author’s, based on Bank Scope

Figure 3: Assets Quality Equity Index

Figure 4: Assets Quality Equity Index

Figure 5: Liquidity Index

Figure 6: Banking Performance Index
In 2005, asset quality index has touched the lowest amount and after that increased gradually, while it has fluctuated in the range of 3 to 4 percent. Cost to income ratio was reduced during 2002-2010. After a smooth increase in 2008, it decreased once again in 2010. Return on average equity decreases from 2005 to 2009, but in 2010 it increases to 7.38. Return on assets ratio and net interest margins have smooth trend during the period studied. Total liquidity indicators have no significant changes during the period studied and loans to assets ratio fluctuate between 50 to 60 percent. Loans to deposits ratio reaches to the highest percent (87.46) in 2005. Assets quality equity indicators were reduced between 2002 and 2004, but since 2005 the trend reversed. After 2005, equity to liquidity and to total asset have continuously moderate downward trend, despite the fact that equity to liability and to deposit are fluctuated during the same period (see table 4 in Appendix I)

III. The Bank Stability Measurement

We use Z score as a measurement tool to assess the banks financial stability. This variable can be considered as a measure of bank risk. The Z Score provides a quantitative measurement into a bank’s financial health and it is based on actual financial information derived from the operating performance of the bank.

The Z-score is a famous measure of bank financial soundness\(^1\) and its popularity stems from the fact that it is inversely related to the probability of a bank’s insolvency, i.e., the probability that the value of its assets becomes lower than the value of the debt. The Z score was first developed by Altman to provide a more effective financial assessment tool for credit risk analysts and lenders and it was widely utilized because it can be fairly objective measure of soundness across different financial institutes.

Bank insolvency is defined where losses overcome equity (CAR ≤ -ROA), CAR is capital-asset ratio and ROA is return as percent of assets. The bank insolvency can be defined as: (CAR+ROA) ≤ 0, If ROA is normally distributed: ROA~N(\(\mu_{\text{ROA}}, \sigma_{\text{ROA}}^2\)), \(\sigma\) is standard deviation of return on

---

assets as a proxy for return volatility. Thus the probability of insolvency can be given as:\(^1\):

\[
p(ROA \leq -\text{CAR}) = p \left( \frac{ROA - \mu_{ROA}}{\sigma_{ROA}} \leq -\frac{\text{CAR} - \mu_{ROA}}{\sigma_{ROA}} \right) = p \left( \frac{ROA - \mu_{ROA}}{\sigma_{ROA}} \leq -z \right) = \Phi_{ROA} (-Z)^2
\]

(\(\Phi\)) demonstrates distribution function of banks standardized returns.

Z-score is defined as \(z = \frac{\mu + \text{CAR}}{\sigma_{ROA}}\).

As we can see, \(Z\) is the inverse of the probability of insolvency. In fact \(Z\) shows the number of standard deviation that a bank’s return on assets has to drop below its expected value before equity is depleted and the bank is insolvent \(^3\) (under the assumption of normality of banks’ returns). In fact, a higher \(Z\)-score indicates that the bank is more stable.

The \(Z\)-score applies equally to banks that use a high risk/high return strategy and those that use a low risk/low return strategy, provided that those strategies lead to the same risk-adjusted returns. If an institute “chooses” to have lower risk-adjusted returns, it can still have the same or higher \(Z\)-score if it has a higher capitalization. In this sense, the \(Z\)-score provides an objective measure of soundness.

Risk sharing in Islamic bank can bring a criticism on \(Z\)-score because this can provide an additional protective buffer in deposit liabilities. Generally based on the Mudarabah, a large part of liabilities in Islamic banks which

---

2. \(p(ROA \leq -\text{CAR}) \leq \frac{\sigma_{ROA}^2}{(\mu + \text{CAR})^2}\), \(Z\)-score is defined \(z = \frac{\mu + \text{CAR}}{\sigma_{ROA}}\) thus we can deduce:

\[
p(ROA \leq -\text{CAR}) \leq \frac{1}{z^2} \quad (1)
\]

\[
p(ROA \leq \mu - z\sigma_{ROA}) \quad (2)
\]

Therefore terms (1) and (2) show the negative relation between \(z\)-score and probability of bank’s failure.

consists of investment can be considered as equity investment\(^1\). According to the Islamic contracts, depositors and bank fix a pre-determined ratio in order to share the profit and return\(^2\). In fact the mechanism of Islamic banks permits these banks to pass their risk to the consumers. Conventional bank can also transfer the risk to their clients through adjustment of loans and deposit rate. Therefore, in both types of banks - conventional and Islamic, the capital and reserves are the proxy variables to estimate the default risk\(^3\).

In other words, these additional layers of protection are ultimately reflected in the banks’ returns and capital, and thereby in their Z-score. Moreover, most of the investment accounts can be withdrawn in a relatively short period of time, as well as the return distribution between the bank and the depositors/investors is pre-determined. This fact diminishes the factual differences in risk profiles associated with the investment accounts comparing with floating-rate deposits and other conventional funding used by commercial banks.

The employed measure is based on Roy (1952), who shows that the probability that current losses would exceed capital is less than or equal to \(1/z^2\), so that the higher level of \(z\) implies lower upper bound of solvency probability\(^4\). Recently, Z-score has been widely used in the empirical banking literature as measure of the probability of bank failure. Boyd and Graham (1986), Hannan and Hanweck (1988), and Boyd et al. (1993), used Z-score as a risk measure, reflecting a bank’s probability of insolvency. The Z-score is a measure of bank stability and shows the distance from insolvency, leverage and volatility and combining accounting measures of profitability.

Boyd et al. (2006) use Z-score to analyze the trade-off between competition and stability in banks across 2500 U.S banks. This risk measure is monotonically associated with a measure of a bank’s probability of failure. Beck and All (2009)\(^5\) used a unique bank-level panel dataset over the period 1995 to 2007, to assess the stability of German banks with different

---

1. Cihak 2008
2. Iqbal and Mirakhor, 2007
3. Cihak 2008
4. Lana Ivićić, Davor Kunovac and Igor Ljuba
5. Thorsten Beck, Heiko Hesse, Thomas Kick and Natalja Von Westernhagen, 2009
ownership structures. They use Z-score as a standard measure of distance from insolvency. Hiroyuki Kiyota analyzed the impact of the crisis on the Africa’s banking system, a comparative analysis of banks’ performance, structure and profitability analysis. Hiroyuki Kiyota analyzes the impact of the crisis on the Africa’s banking system, a comprehensive analysis of bank's performance, structure and profitability analysis. He uses Z-score as a proxy measure of banking stability in order to analyze the bank profitability. Ivičić et al., measure the bank insolvency risk in Central and Eastern Europe (CEE) countries. They measure banking solvency risk by Z-score as a distance-to-insolvency indicator. De Nicolo (2000), Cihak and Hesse (2006) and Meachler et al. (2007)) measure the bank stability by Z-score. Uhde and Heimeshof (2008) analyzed the banking consolidation and financial stability in 2600 banks across the EU-25. They use Z-score as a proxy for financial soundness, a popular measure concerning the distance to insolvency in banking system. Sinha et al. (2009) also used Z-score as a risk index in order to evaluate the riskiness of Indian banks and probability of book value insolvency. Demirguc Kunt and Detragiche studied the relationship between Basel core Principals and bank risk over 3000 banks in 86 countries. They used Z-score proxy for the bank risk, which was considered as a number of standard deviations of bank returns have to fall to wipe out all equity in the bank.

While the Z-score has been widely used in the financial and non-financial literature, De Nicolo (2000) and Beck and All (2009) point some critics to Z-score which can underestimate banking risk. They mention that this indicator cannot capture the probability of a sequence of negative profits. It ignores the potential weakness of the distribution and it considers only the first and second moment of the distribution of profits.

IV. Methodology

We analyzed the strength of Islamic banks in comparison with commercial banks before and after the crisis period, using the data for 429 banks, 113

1. Also we can see the works of Craig and Santos, 1997; DE Nicoló ET AL., 2004; Hess and Cihak (2007).
Islamic banks and 316 commercial banks in 20 countries: Malaysia, Syria, Tunisia, Turkey, Sudan, Iran, Iraq, Kuwait, Lebanon, Jordan, Indonesia, Egypt, Bangladesh, Bahrain, Pakistan, Qatar, Saudi Arabia, United Arab Emirates, Singapore and Yemen, from 2000 to 2010. We have up to 723 data for Islamic banks and 2742 data for commercial banks during the period of study\(^1\).

### Table 2: Overview of the Input Data

<table>
<thead>
<tr>
<th></th>
<th>Large</th>
<th></th>
<th>Small</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Commercial</td>
<td>Islamic</td>
<td>Commercial</td>
<td>Islamic</td>
</tr>
<tr>
<td>Number bank</td>
<td>214</td>
<td>64</td>
<td>102</td>
<td>49</td>
</tr>
<tr>
<td>Number of observation</td>
<td>1930</td>
<td>429</td>
<td>812</td>
<td>294</td>
</tr>
<tr>
<td>Loans/asset</td>
<td>41.0883</td>
<td>8.4973</td>
<td>42.33543</td>
<td>32.72943</td>
</tr>
<tr>
<td>Equity*</td>
<td>683.1249</td>
<td>137.0279</td>
<td>121.9324</td>
<td>87.47322</td>
</tr>
<tr>
<td>Income diversity</td>
<td>0.1588</td>
<td>0.0315</td>
<td>0.102772</td>
<td>0.169539</td>
</tr>
<tr>
<td>Cost income ratio</td>
<td>43.7566</td>
<td>8.3723</td>
<td>66.89609</td>
<td>76.31648</td>
</tr>
<tr>
<td>Total Asset*</td>
<td>6,910.1928</td>
<td>1,025.5662</td>
<td>441.5105</td>
<td>340.6676</td>
</tr>
</tbody>
</table>

Source: Authors calculation based on Bank Scope data.
* Equity and Total asset based on Million USD

To distinguish the impact of bank size on the Z-score we consider two groups of the small and large Islamic and commercial banks. The small and large banks are divided based on their total assets, more than 1 billion $ are considered as large banks and less than 1 billion dollars, are regarded as small banks.

The Z-score varies from -7.062 to 394.936 in Islamic banks, with a mean of 8.86 (for the small Islamic banks Z-score equals to 6.47 and for the large Islamic banks equals to 11.24). For commercial banks Z-score varies from -21.935 to 64.659 with a mean of 7.29 (for the small commercial banks Z-score equal to 7.18 and for the large Islamic banks equal to 7.39). We found that Islamic banks have higher Z-score than commercial banks, but the small Islamic banks have lower Z-score comparing to the small commercial

---

1. We take our data from Bank Scope.
banks; in the large banks it is inversely. In other word, the small commercial banks are more stable than the small Islamic banks.

There is high variability for Z-score across our banks during the period of our study; Z-score is varying from -21 to 179. Therefore, we apply modified Z-score in order to eliminate the outliers. The modified Z-score is determined based on outlier resistant estimators. The median of absolute deviation about the median (MAD) is such an estimator:

\[ \text{MAD} = \text{median} \left[ |x_i - \bar{x}| \right] \]

The test heuristic states that an observation with a modified Z-score greater than three and a half should be labeled as an outlier. This is a reliable test since the parameters used to calculate the modified Z-score are minimally affected by the outliers. The Z-score modified confirm our above results but the results in our two categories get closer.

In the period before crisis, Islamic banks were more stable than commercial banks but in the period after the crisis commercial banks show more stability than Islamic banks. Except for the small Islamic banks, after the crisis, they have higher Z-score than commercial banks.

| Table 3. Decomposition of Z-score (average across the banks in our samples) |
|---------------------|---------------------|---------------------|---------------------|
|                     | All banks           | Large               | Small               |
|                     | Commercial | Islamic | Commercial | Islamic | Commercial | Islamic |
| Z-score              | 7.29       | 8.861   | 7.397      | 11.248   | 7.183      | 6.474   |
| Z-score modified     | 5.829      | 6.136   | 6.118      | 6.847    | 5.541      | 5.425   |
| Z-score regarding to non-oil and oil countries | 8.5375 | 8.583 | 8 | 12.788 | 9.075 | 4.378 |
| Oil producing countries | 8.5375 | 8.583 | 8 | 12.788 | 9.075 | 4.378 |
| Non-oil countries    | 6.628      | 6.983   | 7.096      | 6.239    | 6.16       | 7.727   |
| Before crisis        | 7.5625     | 5.824   | 9.607      | 6.005    | 5.518      | 5.643   |

In oil producing countries the results for Islamic and commercial banks are similar. The large Islamic banks are more stable than commercial banks, while the small commercial banks show more stability than the small Islamic banks. In non-oil countries Islamic banks have more stability than
commercial banks. The results for this group of countries show that the large commercial banks tend to be financially stronger than the large Islamic banks.

We use Z-score as a dependent variable to analyze the stability of Islamic banks comparing to commercial banks, as a function of three sets of variables; key macroeconomic, bank-specific, and structural variables.

Motivated by Nicole (2000), Cihak and Hesse (2006, 2008), Machler et al. (2007) and Ivičić et al. (2008), the function between Z-score and macroeconomic, bank-specific, structural variables is defined as follows:

\[
Z_{it} = C_1 + \sum_{j=1}^{J} C_j M_{jt} + \sum_{k=1}^{K} C_k B_{ikt} + \sum_{w=1}^{W} C_w S_{wt} + \varepsilon_{it},
\]

\((t = 1, \ldots, T)\)

where \((i= 1, \ldots, N)\) indexes banks, \((j= 1, \ldots, J)\), \(M_j\) denote macroeconomic variables, \((k= 1, \ldots, K)\), \(B_{ik}\) denote bank specific variables, \((w= 1, \ldots, W)\), \(S_w\) denote structural variables and \(\varepsilon\) is the residual.

The macroeconomic variables include: real gross national product growth (GDP), inflation rate (P), exchange rate (EX), and the bank specific variables include: total asset (A), equity (E), cost-income ratio (CI), loans to total assets (LA), income diversity (ID), and structural variables include: governance index (G), Herfindahl index (H), dummy for Islamic banks (D1), dummy for financial crisis (D2) and dummy for oil producing countries (D3).

Income diversity is defined as a control variable which shows the differences between the structure of the banks income in Islamic banks and commercial banks (Cihak and Hesse (2008))

1. The income diversity is defined as \(1 - |\text{net interest income-other operating income/total operating income}|\).
2. World Bank, this index wasn’t available for 2001.
Herfindahl index involves sum of squared market shares of banks in the system that is a measure of the size of banks in relation to total banking system and an indicator of the amount of competition among them. In other words, our estimation shows the impact on market concentration on financial stability.

We define three dummy variables in our estimation. The first dummy variable takes one for Islamic banks and 0 otherwise. The second variable takes 0 for the period before financial crisis (2000-2006) and 1 for the period after financial crisis (2007-2010) and third one is regarding to the oil producing countries as; Malaysia, Sudan, Iran, Iraq, Kuwait, Bahrain, Qatar, Saudi Arabia and United Arab Emirates.

We have estimated unbalanced panels for 429 banks (113 Islamic and 316 commercial banks) in 20 countries. Using panel data in general poses the problem when the variables follow a trend. Since our indicators are nearly increasing over time, we use the first differences for all variables to run the regression. As estimation approaches, we apply a two-stage least squares (TSLS) with random effects. Normally if we have a large N (panel data) random effects will be more efficient than fixed effects. Random effects are used when the unobserved individual impact embodies elements that are correlated with the repressors in the model, whether these effects are stochastic or not. We use Housman test to control for the random effects. The bank data used are mostly consolidated data, while we employ unconsolidated data, depending on the availability of data.

V. The Results

Our estimations are given in tables 5 to 10 in Appendix II. In order to have better comparable results we divide our estimations in three groups, small, large and all banks. In order to see the impact of the type of bank on stability we consider a dummy variable which takes the value of 1 if the bank is Islamic and it takes the value of 0 for commercial bank. Our estimations, for the small banks, show negative and significant at 1 percent level, which means that small Islamic banks are relatively weaker than commercial banks; these results are also confirmed in the robust regression. In the large banks
the sign of this dummy is positive and significant at the 10 percent level in all regressions. Therefore, Islamic banks tend to be more stable than commercial banks. These results are confirmed in the robust regressions.

To distinguish the impact of the recent financial crisis, we include a dummy variable, which takes the value of one for the period after crisis (2007-2010) and takes the value of 0 for the period before crisis (2000-2006). In the small banks, this dummy is positive and significant, which means that they maintain growing performance. The coefficients for large banks and total banks have negative and significant signs at 5 percent level. This result shows that the financial crisis had negative impact on stability of large banks.

Banks with higher loans to asset ratios have lower Z-score. The expected correlation between loans ratio and stability is only achieved in the small banks. In the small banks, the coefficients are negative and significant at 5 and 10 percent levels and these results confirm in the robust regressions. Unexpectedly the signs of this coefficient are positive and significant for the large banks, which means that in general, the loans have not negative impact on stability and the performance of these banks are still based on a lending operation. The results of the all banks are not clear.

In order to examine the impact of the loan to asset ratios before and during financial crisis, we generate interaction of these two variables. In the small banks, the coefficients have negative and significant signs at 5 percent level; this result confirms the negative impact of loan increase on stability in the period of crisis. These results are confirmed in the robust regressions. In large and total banks, we cannot conclude clarified results.

The cost-Income ratios have positive relationship with Z-score and its sign is consistently negative and significant in all groups of banks. We use asset as a control variable for the bank size. The stability of all banks decreases as banks become larger. Robust Test has confirmed the results.

We also use Income diversity in order to control the difference in the structure of the bank’s income. In fact, this variable indicates the measure of diversity of bank’s income from traditional sources such as loans comparing to the other income sources. In the small banks, higher income diversity tends to decrease Z-score. This result shows that these banks depend more on lending-based operations rather than other sources of income. In large banks the results are not clear.
Due to the PLS arrangements in Islamic banks, the interaction between Islamic dummy and income diversity could capture the differences of Islamic banks activities comparing to commercial banks. In the small Islamic banks there is no significant relationship between this variable and Z-score, but in large Islamic banks, it has negative and significant impact on stability, suggesting that income in Islamic large banks are more based on traditional lending activities than the small Islamic banks.

The equity variable has positive and strongly significant impact on Z-score in all estimations. The impact of the Herfindahl index is significantly negative in large and total banks. This result confirms that higher concentration is associated with lower stability\(^1\). Nevertheless this result is not confirmed by Robust Test in large banks.

The governance index has positive and strongly significant correlation with z-score in large and total banks. This shows that the better governance is associated with higher stability. These results are confirmed in the robust regressions.

To control the macroeconomic variables, the exchange rate shows no clear correlation with Z-score. In the small banks the economic growth indicates positive and significant correlation with stability and this result confirms strongly in robust test. In all banks this variable has positive and weakly significant correlation with Z-score. In the small banks the correlation between inflation rate and stability is positive and significant at 5 percent level. This result is also confirmed strongly by robust test. In large banks there is no significant relationship between inflation and Z-score; therefore, the results indicate that the small banks are more affected by inflation rate.

The last variable is Dummy for the oil producing countries. The positive sign of this dummy indicates that oil producing countries are more stable than other countries. This variable shows no significant correlation with Z-score in large and all banks.

The oil revenues have direct impact on GDP and economic growth so we examine for the interaction between dummy of oil producing countries and GDP growth. The results show that GDP growth has significant and negative sign in the small banks in oil producing countries. Oil revenues have led to create bigger banks and provide excessive security for the large banks that

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they play important role in economic activities, independent of overall economic situation.

VI. Conclusion

In this paper we investigated the stability of the Islamic banks and compared it to the stability of commercial banks before and after the financial crisis in 2007. Regarding to stability assessment, we used $Z$-score measurement between two groups of the small and large banks. The comparison between the Islamic and commercial banks showed that the large Islamic banks are more stable than the commercial large banks, while the small Islamic banks have lower $z$-score comparing to the small commercial banks. The comparison between the large and small Islamic banks had revealed that crisis has less impact on the Islamic banks when they operate on a small scale. But when the Islamic banks become larger, they can be more vulnerable to credit risk. Furthermore, the $Z$-score index for the Islamic banks revealed unexpected results after the financial crisis; our results show that these banks are also affected by this crisis.

Consider there is no big difference between the oil and non-oil producing countries when we talk about stability. Nevertheless, results have been changed between the small and large banks in the two groups of the Islamic and commercial banks which had shown the large banks in oil producing countries tend to be more stable. Our result from oil producing countries perhaps depends on good governmental financial support for the large public banks, which is confirmed by empirical evidences of the notion that they are too big to fail. The large banks reduce their capital prudential levels which they become more risk taker, because of the implicit governmental protection.

Interesting to notice that our findings are not consistent with the results of Cihak and Hesse who show that the small Islamic banks tend to be financially stronger than the small commercial banks; and the large commercial banks tend to be financially stronger than the large Islamic banks. Different groups of countries or different periods of study and particularly the shock of recent financial crisis could be the cause of the differences in the results. In addition, we can conclude that by passing time, particularly in the last decade, the Islamic banks became larger which increase their activities. In the same time they gain more strength regarding to monitoring the credit risk.
### Table 4: Financial Ratio in Islamic Banks 2002-2010

<table>
<thead>
<tr>
<th></th>
<th>Assets Quality Index</th>
<th>Capital Index</th>
<th>Banking Performance Index</th>
<th>Liquidity Index</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Equity/Total Asset</td>
<td>Equity/Liability</td>
<td>Equity/Deposit and short term Funding</td>
<td>Equity/Liquidity Asset</td>
</tr>
<tr>
<td>2002</td>
<td>5.81</td>
<td>14.9</td>
<td>27.77</td>
<td>12.51</td>
</tr>
<tr>
<td>2003</td>
<td>5.58</td>
<td>11.74</td>
<td>21.39</td>
<td>10.32</td>
</tr>
<tr>
<td>2004</td>
<td>3.90</td>
<td>11.77</td>
<td>19.57</td>
<td>12.02</td>
</tr>
<tr>
<td>2005</td>
<td>3.39</td>
<td>14.76</td>
<td>25.20</td>
<td>18.91</td>
</tr>
<tr>
<td>2006</td>
<td>4.08</td>
<td>14.89</td>
<td>26.28</td>
<td>19.61</td>
</tr>
<tr>
<td>2007</td>
<td>3.78</td>
<td>14.59</td>
<td>25.56</td>
<td>17.71</td>
</tr>
<tr>
<td>2008</td>
<td>3.52</td>
<td>11.11</td>
<td>21.87</td>
<td>16.51</td>
</tr>
<tr>
<td>2009</td>
<td>3.76</td>
<td>13.73</td>
<td>22.65</td>
<td>18.09</td>
</tr>
<tr>
<td>2010</td>
<td>3.48</td>
<td>13.31</td>
<td>22.17</td>
<td>15.40</td>
</tr>
</tbody>
</table>
### Table 5: Regression Result: for Small Banks, 2000-2010

<table>
<thead>
<tr>
<th>Variables</th>
<th>Estimation 1</th>
<th>Estimation 2</th>
<th>Estimation 3</th>
<th>Estimation 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>4.5280</td>
<td>7.2892</td>
<td>7.6379</td>
<td>7.5233</td>
</tr>
<tr>
<td></td>
<td>(0.003)***</td>
<td>(0.000)***</td>
<td>(0.000)***</td>
<td>(0.000)***</td>
</tr>
<tr>
<td>D1</td>
<td>-0.0003</td>
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<td>-2.4678</td>
</tr>
<tr>
<td></td>
<td>(0.0001)***</td>
<td>(0.0067)***</td>
<td>(0.003)***</td>
<td>(0.0033)***</td>
</tr>
<tr>
<td>LA(-1)</td>
<td>0.0034</td>
<td>-0.0254</td>
<td>0.0067</td>
<td>-0.0245</td>
</tr>
<tr>
<td></td>
<td>(0.8064)</td>
<td>(0.0469)**</td>
<td>(0.6363)</td>
<td>(0.0595)*</td>
</tr>
<tr>
<td>LA(-1)*D2</td>
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<td>-0.0757</td>
<td>-0.0757</td>
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<tr>
<td></td>
<td>(0.0215)**</td>
<td>(0.0237)**</td>
<td>(0.0237)**</td>
<td>(0.0237)**</td>
</tr>
<tr>
<td>CI(-1)</td>
<td>-0.0079</td>
<td>0.0071</td>
<td>-0.0091</td>
<td>-0.0053</td>
</tr>
<tr>
<td></td>
<td>(0.1711)</td>
<td>(0.2238)</td>
<td>(0.114)</td>
<td>(0.0372)**</td>
</tr>
<tr>
<td>A(-1)</td>
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<td>-0.0066</td>
<td>-0.0062</td>
</tr>
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<td></td>
<td>(0.0000)***</td>
<td>(0.0000)***</td>
<td>(0.0000)***</td>
<td>(0.0000)***</td>
</tr>
<tr>
<td>ID(-1)</td>
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<tr>
<td></td>
<td>(0.2312)</td>
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<td>(0.1068)</td>
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*Significant at 10%, ** Significant at 5% and *** Significant at 1%
The values in parentheses are probability
Table 6: Regression Result: for Large Banks, 2000-2010

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<th>Variables</th>
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<th>Estimation 3</th>
<th>Estimation 4</th>
</tr>
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<td>8.4858(0.000)***</td>
<td>2.2740(0.1313)</td>
<td>4.1578(0.0014)***</td>
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<td>3.1262(0.0007)***</td>
<td>5.8505(0.0787)*</td>
<td>5.6173(0.0775)*</td>
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<td>-0.0091(0.6829)</td>
<td>0.0119(0.0621)*</td>
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<td>-0.0183(0.0135)**</td>
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<td>-0.0182(0.0147)**</td>
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<td>-0.0005(0.000)***</td>
<td>-0.0005(0.000)</td>
<td>-0.0005(0.000)***</td>
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<td>-5.2573(0.0041)***</td>
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<td>-0.3712(0.000)***</td>
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<td>0.0048(0.000)***</td>
<td>0.0054(0.000)***</td>
<td>0.0056(0.000)***</td>
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*Significant at 10%, ** Significant at 5% and *** Significant at 1%
The values in parentheses are probability
**Table 7: Regression Result: for Total Banks 2000-2010**

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<th>Estimation 4</th>
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<td>(0.000)***</td>
<td>(0.000)***</td>
<td>(0.000)***</td>
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*Significant at 10%, ** Significant at 5% and *** Significant at 1%
The values in parentheses are probability
## Appendix III

Table 8: Regression Result: for small Banks, Robust Estimation 2000-2010

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<th>Estimation 3</th>
<th>Estimation 4</th>
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<td>C</td>
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<td>11.9572 (0.6399)</td>
<td>-35.0848 (0.1215)</td>
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<tr>
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<td>4.5860 (0.1567)</td>
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<td>0.7077 (0.0691)*</td>
<td>1.1659 (0.000)***</td>
<td>0.6523 (0.0917)*</td>
<td>1.1586 (0.0001)***</td>
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<tr>
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<td>0.0592 (0.91638)</td>
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<td>-0.0031 (0.9808)</td>
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*Significant at 10%, ** Significant at 5% and *** Significant at 1%

The values in parentheses are probability
Table 9: Regression Result: for large Banks, Robust Estimation 2000-2010

<table>
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<th>Variable</th>
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<tr>
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<td>(0.1491)</td>
<td>(0.5268)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E(-1)</td>
<td>0.0055</td>
<td>0.0045</td>
<td>0.0064</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0592)*</td>
<td>(0.0448)**</td>
<td>(0.3911)</td>
<td></td>
</tr>
<tr>
<td>D2</td>
<td>-7.5106</td>
<td>-3.4396</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0704)*</td>
<td>(0.0997)*</td>
<td></td>
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</tr>
<tr>
<td>GDP(-1)*D3</td>
<td>3.6758</td>
<td>-0.20998</td>
<td>0.51588</td>
<td>0.2299</td>
</tr>
<tr>
<td></td>
<td>(0.1901)</td>
<td></td>
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</tr>
</tbody>
</table>

Observations: 2684
R-squared: 0.53323

*Significant at 10%, ** Significant at 5% and *** Significant at 1%
The values in parentheses are probability
Table 10: Regression Result: for Total Banks 2000-2010

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimation 1</th>
<th>Estimation 2</th>
<th>Estimation 3</th>
<th>Estimation 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>9.2462 (0.000)***</td>
<td>8.1078 (0.000)***</td>
<td>8.9583 (0.000)***</td>
<td>9.3780 (0.000)***</td>
</tr>
<tr>
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<td></td>
</tr>
<tr>
<td>D1</td>
<td>1.3846 (0.0486)**</td>
<td>2.2253 (0.0011)***</td>
<td>1.5161 (0.0307)**</td>
<td>1.9536 (0.0045)***</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>LA(-1)</td>
<td>0.0019 (0.8961)</td>
<td>-0.0029 (0.7943)</td>
<td>0.0002 (0.9885)</td>
<td>0.0060 (0.9547)</td>
</tr>
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<td></td>
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<td></td>
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</tr>
<tr>
<td>LA(-1)*D2</td>
<td>-0.0419 (0.0713)*</td>
<td>-0.0286 (0.2139)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
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</tr>
<tr>
<td>CI(-1)</td>
<td>-0.0091 (0.0831)*</td>
<td>-0.0105 (0.0460)**</td>
<td>-0.0080 (0.1242)</td>
<td>-0.0110 (0.0369)**</td>
</tr>
<tr>
<td></td>
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</tr>
<tr>
<td>A(-1)</td>
<td>-0.0005 (0.000)***</td>
<td>-0.0005 (0.000)***</td>
<td>-0.0005 (0.000)***</td>
<td>-0.0005 (0.000)***</td>
</tr>
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<td></td>
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</tr>
<tr>
<td>ID(-1)</td>
<td>-0.2107 (0.1878)</td>
<td>-0.3038 (0.0512)*</td>
<td>-0.2996 (0.0523)*</td>
<td>-0.2493 (0.1190)</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>ID(-1)*D1</td>
<td>-4.6234 (0.0003)***</td>
<td>-4.6705 (0.0002)***</td>
<td>-5.0047 (0.006)***</td>
<td>-4.602 (0.0003)***</td>
</tr>
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<td></td>
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</tr>
<tr>
<td>H(-1)</td>
<td>-3.6389 (0.000)***</td>
<td>-3.0670 (0.000)***</td>
<td>-2.9114 (0.000)***</td>
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<td></td>
</tr>
<tr>
<td>G</td>
<td>2.8238 (0.000)***</td>
<td>2.2294 (0.000)***</td>
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</tr>
<tr>
<td>EX(-1)</td>
<td>0.0001 (0.0436)**</td>
<td></td>
<td>2.64E-05 (0.7020)</td>
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</tr>
<tr>
<td>P(-1)</td>
<td>0.0645 (0.0979)*</td>
<td></td>
<td>0.0418 (0.2702)</td>
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</tr>
<tr>
<td>GDP(-1)</td>
<td>-0.1515 (0.2375)</td>
<td></td>
<td>0.1675 (0.0499)**</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>D3</td>
<td>0.247932 (0.8263)</td>
<td></td>
<td>-1.4375 (0.0084)***</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E(-1)</td>
<td>0.0052 (0.000)***</td>
<td>0.0052 (0.000)***</td>
<td>0.0051 (0.000)***</td>
<td>0.0053 (0.000)***</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>D2</td>
<td>-2.9586 (0.0161)***</td>
<td></td>
<td>2.2733 (0.6091)</td>
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<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>GDP(-1)*D3</td>
<td>-0.2870 (0.0910)**</td>
<td></td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>2684</td>
<td>2684</td>
<td>2684</td>
<td>2684</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.97052</td>
<td>0.68092</td>
<td>0.88228</td>
<td>0.77761</td>
</tr>
<tr>
<td>Housman test</td>
<td>143 [0.00]</td>
<td>129[0.00]</td>
<td>129[0.00]</td>
<td>155 [0.00]</td>
</tr>
</tbody>
</table>

*Significant at 10%, ** Significant at 5% and *** Significant at 1%
The values in parentheses are probability
References


A New Mathematical Model to Design Optimum Denomination of Coins and Banknotes Range (ODCBR)

V.R. Ghezavati*

Abstract

When an individual make a cash payment, he needs to consider about the amount to be paid, the coins and banknotes which are available and amount of change. For central banks and retailers, it is of interest to understand how this individual choice process works. The literature of currency use concerns primarily theory; given certain assumptions which can present appreciate denomination range by statistical analysis. Literature surveys try to answer the question that which is the best selection of available coins and banknotes in the wallet to fulfill the charge. There is no mathematical model which can optimize a specific denomination range of coins and banknotes. In this paper, we aim at modeling this process where denomination range of banknotes and coins are optimized through a mathematical model in which all parameters are assumed to be certain in a single period in any economy. Finally, some numerical examples are provided to illustrate the effectiveness of the proposed model.

Keywords: Denomination, Banknote, Coin, Optimization, Mathematical Modeling.

JEL Classification: C61

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1. Introduction and Literature Review

Individuals nowadays have the choice between several modern means of payment in retail transactions. There are two views on optimizing criterion appropriate to this problem. First, it can be assumed an analogy with the problem of Bachet, which concerns the optimal set of standard weights. Based on this approach, the optimal range of denominations of notes and coins has smallest number of denominations with which one can pay any amount in between the smallest transaction and certain upper bound (Telser, 1995). This method believes that all denominations have the same cost of production and that payment amount follows a uniform distribution, this range of denomination will be the primary idea to issue such problem.

The second view which was introduced by Hove (2001) espouses the principle of least effort. In other words, the optimal range of denominations allows the number of tokens exchanged in cash transactions to be minimized (Caianiello et al 1982 and Sumer 1993). The two different views on how to obtain the optimal currency system has led to the result where denominations should be spaced apart by either a factor two or three.

The literature regarded to the currency research is mostly of a theoretical nature. Fascinatingly, there are no optimization researches on cash payments. In other words, there are no studies in which try to achieve the best solution that can optimize a specific denomination range of coins and banknotes. In this paper we aim to fill such gap of the literature. Evidently, it can be simply possible to enumerate the number of times where certain coins and banknotes are dispersed and then returned to the central bank after a time. However, this approach assumes that all banknotes and coins are equally relevant for every possible transaction. In addition, it assumes away that people collect banknotes and coins that money may be lost, and the individuals' wallets do not always contain the relevant denominations for all possible cash transaction. Furthermore, it would be of interest to find what people actually do when they make cash payments.

Over the years, many studies were published in the (economic) literature dealing with several currency researches. In this section, we aim to give a short overview of the existing literature on empirical research of currency
issues. Many papers in the first group deal with the modeling of aggregate currency demand by denomination for forecasting purposes. Forecasting denomination-specific demand is necessary for inventory management and production planning of central banks in their issuing mission. Most econometric models applied for this purpose are regression models that explain denomination-specific demand for bank notes by variables that relate to the two functions of currency, that is, bank notes held for transaction purposes and bank notes held as a store of value (hoarding), see Fase and Van Nieuwkerk (1976, 1977), Browne (1981), Kimball (1981), Fase (1981a), among others. Cramer (1983) simulates the average frequency of use for all denominations in the Dutch range in 1981, by computing the efficient payment methods for a range of Guilder amounts. The number of denominations in circulation, corrected for their frequency of application, then appears to refuse as the face value of the denomination raises.

The second group of currency research concerns all researches of currency hoarding. Hoarding is generally regarded as all holdings of currency that are not intended for transaction reasons. Authors are interested in the development to which currency is hoarded, and the reason why individuals appear to be hoarding rather high amounts. (Anderson (1977), Kimball (1981), Sumner (1990), Sprenkle (1993),) Kimball (1981) finds that this proportion has been declining from the 1960s and is higher for large denominations. Anderson (1977) states that only one third of total outstanding currency is in active use.

Finally, the third group of currency research which we are interested deals with studies that effort to assess the use of denominational ranges in real-world. The aim of such an evaluation is to examine whether the existing composition of denominations meets the need of the public, or receive indications that some changes are necessary. The approaches applied to this problem are rather diverse. Fase (1981a), Payne and Morgan (1981) establish the D-metric approach, consisting of simple rules that may help issuing authorities to compose their currency range, see also Barry (1994) and Mushin (1998).
This paper introduces a new mathematical model where denomination range of banknotes and coins are optimized subject to certainty of all parameters in a single period. In other words, the aim of this paper is to present an optimization model which is able to select the best denomination range of banknotes and coins in a normal economy where they can be consistent for each economy. So, by adjusting parameters and constraints under a specific economy conditions, results can be achieved commensurate with each economy. The structure of the rest paper is organized as follows. Mathematical model ODCBR is presented in Section 2. We present computational results in Section 3. In Section 4, we summarize our conclusions and discuss avenues for future research.

2. Mathematical Formulation

In this section, we will propose and describe more details of mathematical model which can optimize banknote and coin denominations. The aim of this model is to optimize problem from the viewpoint of customer \( k \). In this way, specified amount of money \( w_k \) should be paid in a transaction and this can be fulfilled by a set of available banknotes and coins in his or her wallet. The question is which of these banknotes and/or coins individual will select to fulfill the payment. We aim at modeling this choice and decision process.

There are some notable hints which have to be considered in modeling process as follow:

Amount of \( w_k \) has to be paid, given the content of wallet \( B_k \) for individual \( k \). logically, this payment can be done by different choices of banknotes and coins. This way describes the number and combination of coins and banknotes selected by individual \( k \) to pay amount \( w_k \). Naturally, different combinations should be evaluated in order to response this question. Also, in this problem there is another variable denoting amount of banknotes and coins which are available for the individual at the moment of payment. In optimization process, attention to how an individual choose coins and banknotes is necessary. Also, the following constraints are important and described as follows:
The probability of choosing a payment when it is lower than \( w_k \) is zero.

If there is only one possibility of payment amount, the probability of choosing it is 1.

The probability of all possible values of payment is sum up to 1.

The probability of choosing a payment method when elements of it are expected to be returned as change is zero.

The aim of above assumptions is to specify that the optimization model follows certain parameters and there is no uncertainty based on the different aspects in uncertainty theory.

Furthermore, a framework which is expected the model works appropriate under its assumptions is as follows:

- The upper / lower bound of using each banknote and coin in each transaction is determined. This assumption is because of the fact that no individual does have unlimited access to banknotes and coins in his / her wallet.
- Since there are conflict objectives, multi objective decision making techniques will be applied.
- The mathematical model will be integer programming because of its zero-one and continued variables. Based on the selection process in mathematical model, the model needs to be formulated in discrete decision space.
- Because the model will contain many zero – one variables, branch and bound method will be applied to solve the model for optimality.
- Utility function approach will be applied to integrate objectives of the model.
- Decision solution space will be discrete since amount of payments are described discretely.
- The main objective of the model is to minimize total social costs of all transactions.

2.1 Sets:

I Set of banknotes;
J Set of coins;
R Set of sequences for banknotes;
C Set of sequences for coins;
K Set of individuals;

2.2 Parameters:

- $a_{i}^{b,note}$ The value of $i^{th}$ banknote;
- $a_{j}^{coin}$ The value of $j^{th}$ coin;
- $f_{i}^{b,note}$ Fixed cost of production of $i^{th}$ banknote;
- $f_{j}^{coin}$ Fixed cost of production of $j^{th}$ coin;
- $w_{k}$ Amount of cost which must be paid by individual $k$;
- $n_{i,k}^{b,note}$ Number of type $i$ banknotes which are available in wallet of individual $k$;
- $n_{j,k}^{coin}$ Number of coins type $j$ which are available in wallet of individual $k$;

2.3 Decision Variables:

- $u_{i}^{b,note} = \begin{cases} 
1 & \text{If the } i^{th} \text{ type of banknote is selected to be produced} \\
0 & \text{Otherwise} 
\end{cases}$
- $u_{j}^{coin} = \begin{cases} 
1 & \text{If the } j^{th} \text{ type of coins is selected to be produced} \\
0 & \text{Otherwise} 
\end{cases}$
- $y_{k}$ Amount of money which is paid by individual $k$ to fulfill the payment;
- $B_{k}$ Amount of available budget in $k^{th}$ individual;
- $z_{k}$ Amount of money which is returned to individual $k$;
- $m_{i,k}^{b,note}$ Number of banknote type $i$ which is paid by individual $k$;
- $m_{j,k}^{coin}$ Number of coin type $j$ which is paid by individual $k$;
- $p_{i,k}^{b,note}$ Number of banknote type $i$ which is returned to individual $k$;
- $p_{j,k}^{coin}$ Number of coin type $j$ which is returned to individual $k$;
- $value_{r}^{b,note}$ The value of $r^{th}$ selected banknote;
- $value_{c}^{coin}$ The value of $c^{th}$ selected coin;
A new mathematical model to design …

\[ rank_{i,r}^{b,note} = \begin{cases} 1 & \text{If a banknote type} i \text{ is assigned to sequence} r \\ 0 & \text{Otherwise} \end{cases} \]

\[ rank_{j,c}^{c,coin} = \begin{cases} 1 & \text{If a coin type} j \text{ is assigned to sequence} c \\ 0 & \text{Otherwise} \end{cases} \]

2.4 The Mathematical Model:

2.4.1 Objective Functions

\[ \text{Min } TC1 = \sum_{i} f_{i}^{b,note} \times u_{i}^{b,note} + \sum_{j} f_{j}^{c,coin} \times u_{j}^{c,coin} \quad (1) \]

\[ \text{Min } TC2 = \sum_{i} \sum_{k} (m_{i,k}^{b,note} + p_{i,k}^{b,note}) + \sum_{j} \sum_{k} (m_{j,k}^{c,coin} + p_{j,k}^{c,coin}) \quad (2) \]

\[ \text{Min } TC3 = \sum_{k} \frac{z_{k}}{w_{k}} \quad (3) \]

In order to optimize the proposed problem based on different aspects, it is necessary to apply more than one objective. For this purpose, conflict objectives are considered concurrently and this make solutions to be more practical. In this way, objective (1) minimizes total costs regarding the publication of all banknotes and coins. Optimization of this cost because of its monetary nature is so important for central banks. Objective (2) optimizes the summation of number of applied banknotes and coins in all transaction. This objective leads to minimization of applied banknote and coins. Since each individual and retailer is desired to fulfill transactions efficiently, minimization number of applied banknotes and coins (from individual to retailer to pay money and from retailer to individual for returning the change) is so important for both parties. This term makes one of the total social costs which can be optimized through decision making. Also, objective (3) minimizes all returned money in all transactions by retailers to individuals where the ratio of returned money to the money which is paid is minimized. In other words, this objective prevents returning the exact coins and banknotes to individuals by retailers. So, this model enforces individual to
pay amount of money at the lowest possible so that the returned money is minimized.

Above descriptions illustrate direct and indirect influence of objective functions on final and optimal solution.

2.4.2 Set Constraints:
In this section, all applied limitations and constraints that enable decision maker to select the best solutions are described.

\[ y_k \geq w_k \quad \forall k \]  
\[ y_k \leq B_k \quad \forall k \]  
\[ B_k - \sum_i n_{i,k}^{\text{b.note}} \times a_i^{\text{b.note}} \times u_i^{\text{b.note}} - \sum_j n_{j,k}^{\text{coin}} \times a_j^{\text{coin}} \times u_j^{\text{coin}} = 0 \quad \forall k \]  
\[ y_k - \sum_i m_{i,k}^{\text{b.note}} \times a_i^{\text{b.note}} - \sum_j m_{j,k}^{\text{coin}} \times a_j^{\text{coin}} = 0 \quad \forall k \]  
\[ z_k - y_k + w_k = 0 \quad \forall k \]  
\[ z_k - \sum_i p_{i,k}^{\text{b.note}} \times a_i^{\text{b.note}} - \sum_j p_{j,k}^{\text{coin}} \times a_j^{\text{coin}} = 0 \quad \forall k \]  
\[ \sum_r \text{rank}_{i,r}^{\text{b.note}} - u_i^{\text{b.note}} = 0 \quad \forall i \]  
\[ \sum_c \text{rank}_{j,c}^{\text{coin}} - u_j^{\text{coin}} = 0 \quad \forall j \]  
\[ \sum_i \text{rank}_{i,r}^{\text{b.note}} \leq 1 \quad \forall r \]  
\[ \sum_j \text{rank}_{j,c}^{\text{coin}} \leq 1 \quad \forall c \]
\begin{align*}
  p_{i,k}^{\text{note}} & \leq U^L \times u_{i}^{\text{note}} \quad \forall i, k \\
p_{j,k}^{\text{coin}} & \leq U^L \times u_{j}^{\text{coin}} \quad \forall j, k \\
\text{value}^{\text{note}}_r & - \sum_i \text{rank}^{\text{note}}_{i,r} \times a_{i}^{\text{note}} = 0 \quad \forall r \\
\text{value}^{\text{coin}}_c & - \sum_j \text{rank}^{\text{coin}}_{j,c} \times a_{j}^{\text{coin}} = 0 \quad \forall c \\
\text{value}^{\text{note}}_r & \geq 2 \times \text{value}^{\text{note}}_{r-1} \quad \forall r \\
\text{value}^{\text{coin}}_c & \geq 2 \times \text{value}^{\text{coin}}_{c-1} \quad \forall c \\
\text{value}^{\text{note}}_r & - \sum_{\alpha=1}^{r-1} \text{value}^{\text{note}}_{\alpha} \geq 0 \quad \forall r \\
\text{value}^{\text{coin}}_c & - \sum_{\beta=1}^{c-1} \text{value}^{\text{coin}}_{\beta} \geq 0 \quad \forall c \\
m_{i,k}^{\text{note}} & \leq n_{i,k}^{\text{note}} \times u_{i}^{\text{note}} \quad \forall i, k \\
m_{j,k}^{\text{coin}} & \leq n_{j,k}^{\text{coin}} \times u_{j}^{\text{coin}} \quad \forall j, k \\
u_{j}^{\text{coin}} + u_{i}^{\text{note}} & \leq 1 \quad \forall j, i \text{ if } a_{i}^{\text{note}} = a_{j}^{\text{coin}} \\
u_{i}^{\text{note}}, u_{j}^{\text{coin}}, \text{rank}^{\text{note}}_{i,r}, \text{rank}^{\text{coin}}_{j,c} & \in \{0, 1\} \\
y_k, B_k, z_k, \text{value}^{\text{note}}_r, \text{value}^{\text{coin}}_c & \geq 0 \quad (26) \\
m_{i,k}^{\text{note}}, m_{j,k}^{\text{coin}}, p_{i,k}^{\text{note}}, p_{j,k}^{\text{coin}} & \text{Integer} \\
\end{align*}

Set constraints (4) and (5) ensure that amount of money paid to fulfill the payment must be greater than \( W_k \) and less than available money. Set constraint (6) computes available budget for individual \( k \) based on his / her available banknotes and coins. Set constraint (7) denotes amount of money which is paid to fulfill the payment based on used banknotes and coins. Set
constraint (8) guarantees that amount of money paid to fulfill the payment will be equal to the sum of returned money and wk. In other words, this constraint computes amount of returned money for individual \( k \) in each transaction. Set constraint (9) determines which combination of banknotes and coins should be selected in order to find the amount of returned money. Set constraints (10) and (11) illustrate that if a banknote / coin is selected to be issued by central bank in transactions must be assigned to a sequence. Set constraints (14) and (15) guarantee that a retailer can use a banknote / coin once it is issued by central bank. Set constraint (16) and (17) compute the value of banknote / coin which is assigned to each sequence.

Note: In order to formulate the problem efficiently, it is necessary to order the value of selected coins and banknotes in ascending mode. In other words, the least value of banknotes has the sequence number 1 and the maximum value of banknotes has the last ranking. Such approach is one of the novel formulation techniques which can be applied for 0-1 models. For example, if it is decided to publish banknotes 200, 500 and 100, then banknote 100 will have the rank 1, banknote 200 will have the rank 2 and also, the banknote 500 will have the rank 3. As it can be seen, the value of published banknotes and coins will be ordered ascending in the model by set of variables. By this way, decision maker will be able to find solutions efficiently because of his access to all feasible solutions in decision space.

Set constraints (18) and (19) show that the value of a banknote / coin in each sequence must be at least 2-fold of previous sequence. Set constraints (20) and (21) make sure that the value of each banknote / coin in each sequence is greater than summation of the value of previous banknotes / coins. Set constraints (22) and (23) indicate the upper limit of the usage of each banknote / coin for each individual in each transaction based on the available coins / banknotes. Also, set constraint (24) imposes that if a value of money can be published in both forms of banknote and coin, then only one of them can be produced by the central bank. For example, it may be possible that decision maker wants to know whether he should produce 100 units of
money in banknote form or coin. This constraint forces the model to select at least one of them in final solution. Finally, set constraints (25), (26) and (27) indicate the type of decision variables.

Among above discussed constraints, two of them (18 and 20) because of their important influence on the final solution should be described more. In order to maximize diversity of amount of a payment, set constraint (20) is considered where it makes sure that the value of each banknote in each sequence must be greater than summation of the value of previous banknotes. For example, if banknotes 2, 5 and 10 are existing, so the next banknote should be at least one unit more than 2+5+10 or 18. It is because of the fact that a banknote such as 12 which is less than 2+5+10 can be generated by combination of 2 and 10 and thus, this banknote has no influence on increasing diversity of payments if it is produced. On the other hand, a banknote 18 cannot be generated by the previous banknotes and can develop and maximize the interval of payments. This hint must be considered in the proposed mathematical model.

Also, in order to minimize number of published banknotes in circulation in all transactions, the value of each banknote must be at least 2-fold of previous banknote. Also, this is because of the fact that set constraint (20) forces each banknote to be more than summation of previous banknotes. In other words, based on the constraint (20), the value of each banknote is at least equal to summation of all previous ones. So, decision maker do not need to publish new banknote at most one-fold value of an existing banknote since this can be possible by the current banknote and previous banknotes. For instance, if banknote 10 is existing, then to pay 20 units of cost, it is possible to use 2 banknotes 10 units instead of one banknote 20 units or combination of banknote 10 and previous banknotes (it is noted that previous banknotes are at most 10 units of money, so these banknotes and banknote 10 can generate payment of (20). By this way, there is no need to publish banknote 20. It is noted that by the objective function (2), total number of used banknotes and coins are minimized through optimization process and the model has to find balanced solution which can satisfy both two aspects of the problem.
3. Computational Results:

In order to illustrate the effectiveness of the proposed model, we give some numerical examples that are performed on a personal computer. All algorithms considered in this study were coded in Lingo 11 software and run on a Pentium IV PC with 2.6 GHz CPU and 2GB RAM.

As it was discussed earlier, the proposed mathematical model is mixed integer programming where it contains 0-1 and continuous variables. Since this model falls in class of multi objective decision making problems, multi objective decision making (MODM) techniques must be applied to solve model for optimality. In this way, branch and bound algorithm is selected for the solver.

Our proposed model is a multi-objective, integer programming model whose objective functions are completely inconsistent; we use the LP-metric method which is one of the famous multi criterion decision making (MCDM) methods for solving multi-objective problems with inconsistent objective functions. According to this method, a multi-objective problem is solved regarding each objective function separately, and then a single objective is formulated which aims to minimize the summation of normalized differences between each objective and its optimal value. Since there is no solution which can optimize all objective functions concurrently, final solution which can be reached by this way will be close enough to all optimal solutions. In this way, all objective functions can be satisfied similarly. For our proposed model assume that three objective functions are named as $TC_1$, $TC_2$ and $TC_3$. According to the basics of LP-metric method, the model should be solved for every one of these three objective functions, separately. Assume that the optimal values for these three problems are $TC_1^*$, $TC_2^*$ and $TC_3^*$. Now, the LP-metric objective utility function (28) can be formulated as follows:

$$
\text{Min } Z = \left[ w_1 \frac{TC_1 - TC_1^*}{TC_1^*} + w_2 \frac{TC_2 - TC_2^*}{TC_2^*} + w_3 \frac{TC_3 - TC_3^*}{TC_3^*} \right]
$$

(28)

Here, $w_1$, $w_2$ and $w_3$ are the weights of the objective functions which are given by the decision maker. In this paper, all weights are assumed to be
equal to 1. Using such LP-metric objective function and considering the model constraints, we have a single objective, integer programming model, which can be solved by linear programming solvers. We used Lingo 11.0 software to solve our proposed model.

To evaluate efficiency of model a numerical example is designed. In this example, the aim is to verify model performance in order to optimize denomination of banknotes and coins. Also, as it was discussed, the aim of the proposed model was to demonstrate the optimum denomination range of coins and banknotes. So, the final results should be applicable for all economies. Thus, the values of parameters must be generated with respect to all conditions and rules so that they can be feasible in all economies. It is assumed that there are 20 different individuals where they want to pay their transactions by the best selection of available banknotes and coins. In order to cover all situations and also simplify computations, we assumed that 10 individuals have transactions which are fulfilled by coins and the other individuals have transactions which are fulfilled by banknotes. Also, the model has to decide 100 units of money should be issued in coin form or banknote. The value of candidate banknotes and coins in order to select / not select are in tables 1 and 2 as follows:

**Table 1: The value of candidate banknotes**

\[ a_{i}^{b,\text{note}} = \]

<table>
<thead>
<tr>
<th>b.note #1</th>
<th>b.note #2</th>
<th>b.note #3</th>
<th>b.note #4</th>
<th>b.note #5</th>
<th>b.note #6</th>
<th>b.note #7</th>
<th>b.note #8</th>
<th>b.note #10</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>200</td>
<td>500</td>
<td>700</td>
<td>1,000</td>
<td>2,000</td>
<td>3,000</td>
<td>5,000</td>
<td>8,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8,000</td>
<td></td>
<td></td>
<td></td>
<td>10,000</td>
</tr>
</tbody>
</table>

**Table 2: The value of candidate coins**

\[ a_{j}^{\text{coin}} = \]

<table>
<thead>
<tr>
<th>Coin #1</th>
<th>Coin #2</th>
<th>Coin #3</th>
<th>Coin #4</th>
<th>Coin #5</th>
<th>Coin #6</th>
<th>Coin #7</th>
<th>Coin #8</th>
<th>Coin #9</th>
<th>Coin #10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>8</td>
<td>10</td>
<td>15</td>
<td>20</td>
<td>40</td>
<td>50</td>
</tr>
</tbody>
</table>

Furthermore, it is assumed that the costs regarded to production of banknotes / coins (tables 3 and 4) are as follows:
Table 3: The costs of production banknotes

\[ f_{i, \text{note}} = \]

<table>
<thead>
<tr>
<th>b.note #1</th>
<th>b.note #2</th>
<th>b.note #3</th>
<th>b.note #4</th>
<th>b.note #5</th>
<th>b.note #6</th>
<th>b.note #7</th>
<th>b.note #8</th>
<th>b.note #9</th>
<th>b.note #10</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>400</td>
<td>1,000</td>
<td>1,400</td>
<td>2,000</td>
<td>4,000</td>
<td>6,000</td>
<td>10,000</td>
<td>16,000</td>
<td>20,000</td>
</tr>
</tbody>
</table>

Table 4: The costs of production coins

\[ f_{j, \text{coin}} = \]

<table>
<thead>
<tr>
<th>coins #1</th>
<th>coins #2</th>
<th>coins #3</th>
<th>coins #4</th>
<th>coins #5</th>
<th>coins #6</th>
<th>coins #7</th>
<th>coins #8</th>
<th>coins #9</th>
<th>coins #10</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>6</td>
<td>9</td>
<td>15</td>
<td>24</td>
<td>30</td>
<td>45</td>
<td>60</td>
<td>120</td>
<td>150</td>
</tr>
</tbody>
</table>

The number of coins which can be available for each individual once a coin is selected to be generated is as follows in table 5. Since it is assumed that customer number 1 to 10 fulfil their payments by coins, thus number of available coins only is consider for them and customers 11 to 20 cannot use coins.

Table 5: The number of available coins for each individual

\[ n_{j,k}^{\text{coin}} = \]

<table>
<thead>
<tr>
<th>Customer No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coin#1</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Coin#2</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Coin#3</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Coin#4</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Coin#5</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Coin#6</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>5</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Coin#7</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Coin#8</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Coin#9</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Coin#10</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Also, the number of available banknotes for individual 11 to 20 for all types of banknotes is considered to be 3. In other words, it is assumed that each individual has 3 available banknotes to pay his / her transaction.
Finally, the cost which must be paid by individual \( k \) is as follows in table 6:

**Table 6: Amount of cost which must be paid by each individual**

\[
w_k =
\]

<table>
<thead>
<tr>
<th>Co.1</th>
<th>Co.2</th>
<th>Co.3</th>
<th>Co.4</th>
<th>Co.5</th>
<th>Co.6</th>
<th>Co.7</th>
<th>Co.8</th>
<th>Co.9</th>
<th>Co.10</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>15</td>
<td>35</td>
<td>55</td>
<td>70</td>
<td>90</td>
<td>110</td>
<td>135</td>
<td>118</td>
<td>100</td>
</tr>
<tr>
<td>Co.11</td>
<td>Co.12</td>
<td>Co.13</td>
<td>Co.14</td>
<td>Co.15</td>
<td>Co.16</td>
<td>Co.17</td>
<td>Co.18</td>
<td>Co.19</td>
<td>Co.20</td>
</tr>
<tr>
<td>2,500</td>
<td>800</td>
<td>8,600</td>
<td>15,400</td>
<td>22,500</td>
<td>3,300</td>
<td>44,600</td>
<td>52,000</td>
<td>12,900</td>
<td>20,000</td>
</tr>
</tbody>
</table>

After data entry to the solver, the model has been run and optimum results are achieved. In final and optimum solution, amount of objective function has reached to 0.176. This means that each objective functions which conflict to each other has kept out 17.6% from its optimum value. For more information amount of each objective is shown below:

- TC1 = 35461.00
- TC2 = 80.00
- TC3 = 0.2545621E-01

In order to illustrate the results, amount of each important decision variable is described. The value of \( u^b_i \) denotes select / not select of suggested banknote denomination is as follows in table 7:

**Table 7: Selection or not selection (rejection) of candidate banknotes**

<table>
<thead>
<tr>
<th>( u^b_1 )</th>
<th>( u^b_2 )</th>
<th>( u^b_3 )</th>
<th>( u^b_4 )</th>
<th>( u^b_5 )</th>
<th>( u^b_6 )</th>
<th>( u^b_7 )</th>
<th>( u^b_8 )</th>
<th>( u^b_9 )</th>
<th>( u^b_{10} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

- Above results show that the mathematical model has to select denominations 100, 500, 2000, 5000 and 10000 banknotes to fulfill payments.
Also, the value of $u_j^{\text{coin}}$ in which indicated select / not select of suggested coin denomination is as follows in table 8:

**Table 8: Selection/rejection of candidate coins**

<table>
<thead>
<tr>
<th>$u_1^{\text{coin}}$</th>
<th>$u_2^{\text{coin}}$</th>
<th>$u_3^{\text{coin}}$</th>
<th>$u_4^{\text{coin}}$</th>
<th>$u_5^{\text{coin}}$</th>
<th>$u_6^{\text{coin}}$</th>
<th>$u_7^{\text{coin}}$</th>
<th>$u_8^{\text{coin}}$</th>
<th>$u_9^{\text{coin}}$</th>
<th>$u_{10}^{\text{coin}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

The mentioned results say that the mathematical model has to select denominations 2, 5, 10, 20 and 50 coins to fulfill the individuals' payments.

Also, to explore the results, the value of 3 other variables $w_k$, $y_k$ and $z_k$ are shown in the following table 9:

**Table 9: Optimum solution report**

<table>
<thead>
<tr>
<th>Customer No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>$w_k$</td>
<td>7</td>
<td>15</td>
<td>35</td>
<td>55</td>
<td>70</td>
<td>90</td>
<td>110</td>
<td>135</td>
<td>118</td>
<td>100</td>
</tr>
<tr>
<td>$y_k$</td>
<td>7</td>
<td>15</td>
<td>35</td>
<td>55</td>
<td>70</td>
<td>90</td>
<td>110</td>
<td>135</td>
<td>118</td>
<td>100</td>
</tr>
<tr>
<td>$z_k$</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

As it can be seen in above table, in the small transactions where the payment is fulfilled by coins, amount of returned money as change is zero and in large transactions where the payment is fulfilled by banknotes, amount of returned money is minimized. Let discuss results for customer number 17. This customer has to pay 44,600 units of money. Based on the contents of his wallet he paid 45100 units of money (1 banknote 100, 3 banknotes 5000 and 3 banknotes 10000 or 1×100+3×5000+3×10000). In this way, the retailer has returned 1 banknote 500 to him with minimum number of used banknotes. As
it can be seen all constraint, limitations and objectives are satisfies through this solution. Also, consider customer 14. He has to pay 15400 units of money. So, based on the available coins and banknotes in his wallet, he decided to pay 15500 units of money to fulfill his payment. Finally, the retailer has returned 100 one banknote units. For the other individuals the same expressions are required.

The aim of the proposed model and also computational results was to prove the best denomination range of banknotes (100, 500, 2000, 5000 and 10000) and coins (2, 5, 10, 20 and 50) under an optimization and mathematical model in a normal economy with conventional limitations where the achieved results as can be observed above are consistent with previous statistical and empirical results. Above results are consistent with all economies and also, by adjusting parameters based on the specific conditions, commensurate results can be achieved with each economy.

4. Conclusion and Future Directions:

We introduced a new contribution at modeling in this paper to answer how an individual selects optimum coins and banknotes to fulfill his / her payment where denomination range of banknotes and coins were optimized through a mathematical model in which all parameters are assumed to be certain in a single period. This is because of the fact that there is no mathematical optimization model which can optimize a specific denomination range of coins and banknotes. Also, in order to illustrate model efficiency, some numerical instances were proposed. As it could be found from the results, the mathematical model can adapt to the results of empirical and statistical models to find denomination of coins and banknotes. For future directions, the following issues can be suggested:

- Developing model under uncertain situations where it can be optimized through stochastic optimization, robust optimization and fuzzy theory based on the type of uncertainty.
- It can be interesting that introduced model can be run under different conditions of different economies (real-world data) and the results can be compared together.
Introducing solution procedures in order to solve the model in large size problems.

Considering inflation rate in modeling process.

Development of the proposed model under multi period conditions and dynamic programming.

Integrating the proposed model with perspectives and objectives of central bank.

These critical issues remain for future studies.
References:


